SYNAPSE
CCD Detection System
User Manual

Part Number 81100 – Revision 2

HORIBA JOBIN YVON

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- Following all precautions
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Preface

This manual explains how to install, operate, troubleshoot and maintain your Synapse CCD (Charge Coupled Device) detection system, as well as describes salient features and overall system specifications. Information is also provided regarding the minimum system requirements necessary for successful system operation and optimum performance.

Depending on the purchased system configuration, your system may contain more than one HORIBA Jobin Yvon operating manual. The general guidelines presented below may assist you in finding the specific manual that is the most informative on a particular subject:

- Each manual generally covers a specific product along with the features and accessories particular to and/or contained within that product.
- Accessories that can be applied to other products are normally covered by separate documentation.
- Software that is exclusively used with one instrument or system is covered in the manual for that product.
- Software that can be used with a number of products is covered in its own manual.
- If you are reading about a product that interacts with other products, you will be referred to additional documentation as necessary.

Chapter 1: System Description and Specifications

Introduction

The Synapse CCD is a complete solution for modern spectroscopic measurements. This compact CCD detector is designed to interact with all HORIBA Jobin Yvon spectrometers and provide highly sensitive detection for any experiment. Its flexible design can handle any application from simple absorbance to the most difficult Raman or photoluminescence measurements.

Synapse is a complete CCD detection system, providing two-dimensional photo-detection, while offering outstanding sensitivity, high speed, low noise, ruggedness, durability, and high reliability. The Synapse platform supports a wide variety of chip formats and sensor characteristics to meet your intended spectroscopic application. Every Synapse CCD is factory tested for linearity, full well capacity, and read noise performance.

Features include an integrated controller, thermoelectric air cooling, and a maintenance-free, sealed vacuum chamber. Low noise amplifiers are precisely located next to the CCD sensor to minimize any noise from the external environment. Communication between the detector and the host computer is achieved via a high speed USB 2.0 computer interface.

Additionally, Synapse allows flexibility in selection and storage of detector parameters for X and Y binning, area definition, selection of various gains and pixel processing speeds, and advanced trigger operation as well as TTL output. All functions are controlled via SynerJY®, HORIBA Jobin Yvon's spectroscopic application software.

The primary components making up the Synapse CCD detection system are:

- CCD Detector Head
- Power Supply Unit
- Spectroscopic Application Software

All Synapse equipment is tested for compliance with both the EMC Directive 89/336/EEC and the Low Voltage Directive for Safety 73/23/EEC, and bears the international CE mark as indication of this compliance. HORIBA Jobin Yvon guarantees the product line's CE compliance only when original HORIBA Jobin Yvon supplied parts are used. Appendix B provides a table of all CE Compliance tests and standards used to qualify this product.

Table I. System Level Specifications for the Synapse CCD Detection System

Specifications			
System Parameter		Units / Description	
Sensor			
Operating Temperature	Temperature	-70 °C (203 K) @ T_A = +20 °C	
	Resolution Step Size	0.1 °C	
	Long Term Stability	± 0.1 °C	
Noise		See Notes 1 and 2	
Non-Linearity		< 0.4% @ 20 kHZ < 1 % @ 1 MHz	
Full Well Capacity		See Notes 1 and 2	
Effective Dynamic Range		See Notes 1 and 2	
Dark Current		See Notes 1 and 2	
Pixel Processing			
ADC Precision		16 bit	
ADC Dynamic Range		65, 535 maximum	
Data Conversion Speed		20 kHz and 1 MHz programmable via software	
Gain Settings		High sensitivity, best dynamic range, and high light programmable via software (See Note 3)	
Binning and ROI		Supports flexible binning patterns and areas programmable via software	
Exposure Time		0.001 s minimum to 49.71 days maximum	
Vertical Clock Speeds		8 µs to 36 µs programmable via software, See Note 2	
Electrical Interfaces			
Computer Interface		USB 2.0	
Inter-Integrated Circuit (I^2C) Bus		Two-wire, synchronous, serial interface Standard Mode: 100 kb/s Fast Mode: 400 kb/s	
Auxiliary Analog Input Channel	Voltage Input Range	+/- 10 V, +/- 1 V, +/- 0.1 V, and +/- 0.01 V programmable via software	
	Current Input Range	+/-10 µA, +/- 1 µA , +/- 0.1 µA, and +/- 0.01 µA programmable via software	
	Gain Settings	Four gain settings of 1/10/100/1000 programmable via software	
	ADC Resolution	16 bit	
External Trigger Input (TTL In)		TTL level signal, programmable rising/falling edge triggering via software	
TTL Output (TTL Out)		TTL level signal, configurable output and polarity via software	
Shutter Output Excitation Drive		Shutter Coil Resistance	12 Ω
		Shutter Pulsed Voltage to Open	+60 V DC
		Shutter Hold Voltage	+5 V DC
		Operating Frequency	40 Hz maximum rep rate
Power Requirements			
Input Line Voltage		85-264 V AC continuous / universal	
Input Line Frequency		47 – 63 Hz	
Input Power		110 W typical	
Optical Distance from Sensor to Front Flange			
Optical Distance		13.87 mm (.546 in)	
Mechanical			
Dimensions (L x W x H)	Detector Head	178 mm (7.02 in), 113 mm (4.45 in), 113 mm (4.45 in)	
	Power Supply Unit	195 mm (7.67 in), 130 mm (5.10 in), 94 mm (3.70 in)	
Weight	Detector Head	2.108 kg (4.52 lb)	
	Power Supply Unit	1.650 kg (3.18 lb)	

Notes:

1. All specifications subject to change without notification.
2. System attributes, such as total system noise, full well capacity, effective system dynamic range and dark current are a function of the selected sensor in combination with the Synapse detection system and as such, are addressed in separate CCD specification documents for all HORIBA Jobin Yvon sensor offerings.
3. Calibration data, defining the transfer function for the incorporated CCD sensor in electrons /count for each available gain setting is provided with each Synapse detector.

Chapter 2: System Requirements

Synapse CCD systems have minimum system requirements that are necessary for successful operation and optimum performance. This section covers issues related to system attributes such as input power, physical environment, ventilation, grounding/safety, host computer requirements and general maintenance. The user is encouraged to read this chapter in its entirety prior to installing and powering up the detection system.

Input Power Requirements

The Synapse operates from universal AC single-phase input power over the range of 85 to 264 V AC with a line frequency of 47 to 63 Hz. This AC input power is applied to a two-pole fusing power entry module located on the rear panel of the power supply unit. This module incorporates two 5 x 20 mm IEC approved, 2.0 A, 250 V, ceramic slow blow fuses (Cooper Bussman P# BK/GDC-2A or equivalent) to protect against line disturbances/anomalies outside the system's nominal operating power range.

Environmental Requirements

- Storage temperature from -25 °C to +55 °C
- Operating ambient temperature range +25 °C ± 5 °C
- Relative humidity ≤ 80% non-condensing

Ventilation Requirements

Fans are incorporated in both the power supply unit and detector head to cool the enclosed electronics and maintain optimum system performance. Care should be taken to ensure that the ventilation slots on both the detector head and power supply unit are free from obstruction in order to maintain an adequate level of air flow for proper operation. Keep a minimum distance of 2 inches between the vents of the equipment and any walls or surrounding equipment.

General Safety Requirements

The following general safety precautions must be observed during all phases of operation of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture and intended use of instrument. HORIBA Jobin Yvon assumes no liability for the customer's failure to comply with these requirements. Certain symbols (listed on the following page) may be found on the instrument, supporting equipment or used throughout the text for special conditions when operating the instrument.

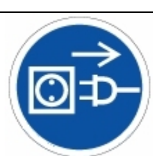
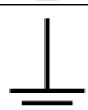
To prevent permanent damage to your system, please observe the following safety precautions:

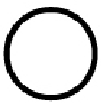
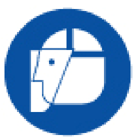
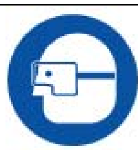
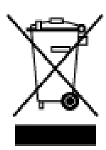
- Do not block the air vents of the detector head or power supply unit. Preventing the free flowing air can overheat and permanently damage the CCD.
- Prior to the application of power, ensure that the ground prong of the power supply power cord is properly connected to a wall outlet or power strip that provides for a protective earth ground connection.
- Do not connect or disconnect any cables to or from the detector head while the system is powered on.
- The sensor and detector head electronics are all very sensitive to Electrostatic Discharge (ESD). When installing the system, stand on a conductive mat and wear a grounded ESD wrist strap.

Safety Symbols

Please refer to the table below to locate and identify the important safety symbols on the instrument and supporting equipment.

Table II. Safety Symbols

Symbol	Name	Meaning
	Caution	Refer to the instruction manual in order to protect against damage to the product.
	Hazardous voltage	Caution, risk of electrical shock.
	Hot-surface	Caution, hot surface.
	Cryogenic surface	Caution, severe burn
	Explosion	Explosion hazard! Wear explosion-proof goggles, full-face shield, skin-protective clothing, and protective gloves.
	Humidity	Caution, excessive humidity, if present, can damage certain equipment.
	Ultraviolet light	Ultraviolet light! Wear protective goggles, full face shield, skin-protective clothing, and UV-blocking gloves. Do not stare into light.
	Intense ultraviolet, visible, or infrared light.	Intense ultraviolet, visible, or infrared light! Wear light-protective goggles, full-face shield, skin-protective clothing, and light-blocking gloves. Do not stare into light.
	Disconnect before servicing	Disconnect instrument from mains before servicing.
	Earth (ground) terminal	Indicates a circuit-common connected to grounded chassis.

	Protective earth (ground) terminal	Indicates a protected circuit-common connected to grounded chassis.
	Alternating current	Indicates an alternating current.
	On (supply)	Indicates power is on.
	Off (supply)	Indicates power is off.
	Wear gloves	Wear protective gloves to protect hands from burns, chemicals, or other hazards.
	Wear face shield	Wear a full face shield to protect face from dangers such as ultraviolet, visible, or infrared light or from explosion hazards.
	Wear protective goggles	Wear protective goggles to protect eyes from dangers such as ultraviolet, visible, or infrared light and chemicals.
	See instruction manual	Refer to the instruction manual, in order to protect against damage to the product.
	WEEE mark	Electrical and electronic equipment meets the requirements of the WEEE Directive 2002/96/EC; indicates separate collection and disposal for electrical and electronic equipment.

Computer Requirements

Synapse CCD detection systems are configured and controlled via HORIBA Jobin Yvon’s SynerJY software. To successfully install SynerJY, the your computer system must be equipped with the following:

Software

- Windows 2000 or Windows XP operating system

Hardware

- Meets minimum requirements for running Windows 2000 or Windows XP
- 128 MB RAM
- 200 MB disk space
- One free USB 2.0 port for USB communications

General Maintenance Requirements

Cleaning the Detector Head

Users are recommended to periodically clean the Synapse detector by wiping it down with a clean, damp cloth. This procedure should only be performed on external surfaces after any supplied ESD covers have been re-affixed to their respective electrical interfaces. Do not use any solvents, soaps, or abrasives when cleaning components as these products can damage surface finishes.

Cleaning the Dust Cover of the Power Supply Unit

The dust cover of the power supply unit must be periodically (a minimum of once every six months) removed and cleaned. To clean the dust cover:

1. Make sure that the power switch located on the back of the power supply unit is set to the off (“O” symbol) position.
2. Remove the four Phillips head screws that secure the dust cover to the unit.
3. Remove the dust cover, holding it several feet away from the unit.

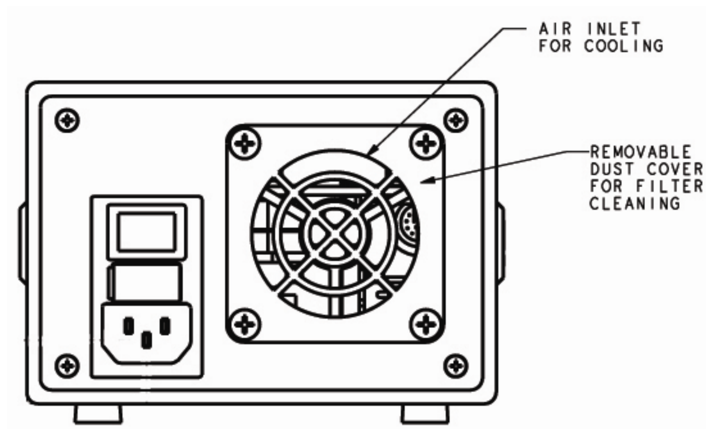


Figure 1. Removable Dust Cover of Power Supply Unit

4. Hold a can of compressed air about 2” away from the dust cover, and use short blasts of air to remove all dust from the cover.

CAUTION

When using compressed air, read and follow the usage information, usage directions, and caution warnings specific to the brand of air you are using. Use the product in a well-ventilated area and do not use near potential ignition sources - compressed air can ignite under certain circumstances.

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5. Once the cover is clean and completely dry, re-secure it to the power supply unit using the four Phillips head screws.

Chapter 3: Detector System Installation

Installation Overview

Before the operational power-up phase, you must install and set up your Synapse CCD detection system. It is recommended that you read this chapter thoroughly and follow the steps in the order listed below for proper installation and startup.

- Unpacking and Equipment Inspection
- Installing Application Software
- Mounting the Synapse Detector to a Spectrograph
- Connecting Electrical Interface Cables

CAUTION

Electrostatic discharge (ESD) may damage components of the Synapse CCD detection system if proper precautions are not taken. The sensor and detector head electronics are all very sensitive to ESD. When installing the system, stand on a conductive mat and wear a grounded ESD wrist strap. The computer must be turned off; however, its power cord should be connected to a grounded outlet to provide a proper chassis to earth ground.

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Note: It must be emphasized that the HORIBA Jobin Yvon warranty on Synapse does not cover damage to the sensor or the system's electronics that arises as a result of improper handling, including the effects of electrostatic discharge (ESD).

Unpacking and Equipment Inspection

Carefully unpack your Synapse system, examining each component for possible shipping damage. Figure 3 below depicts the individual system components.

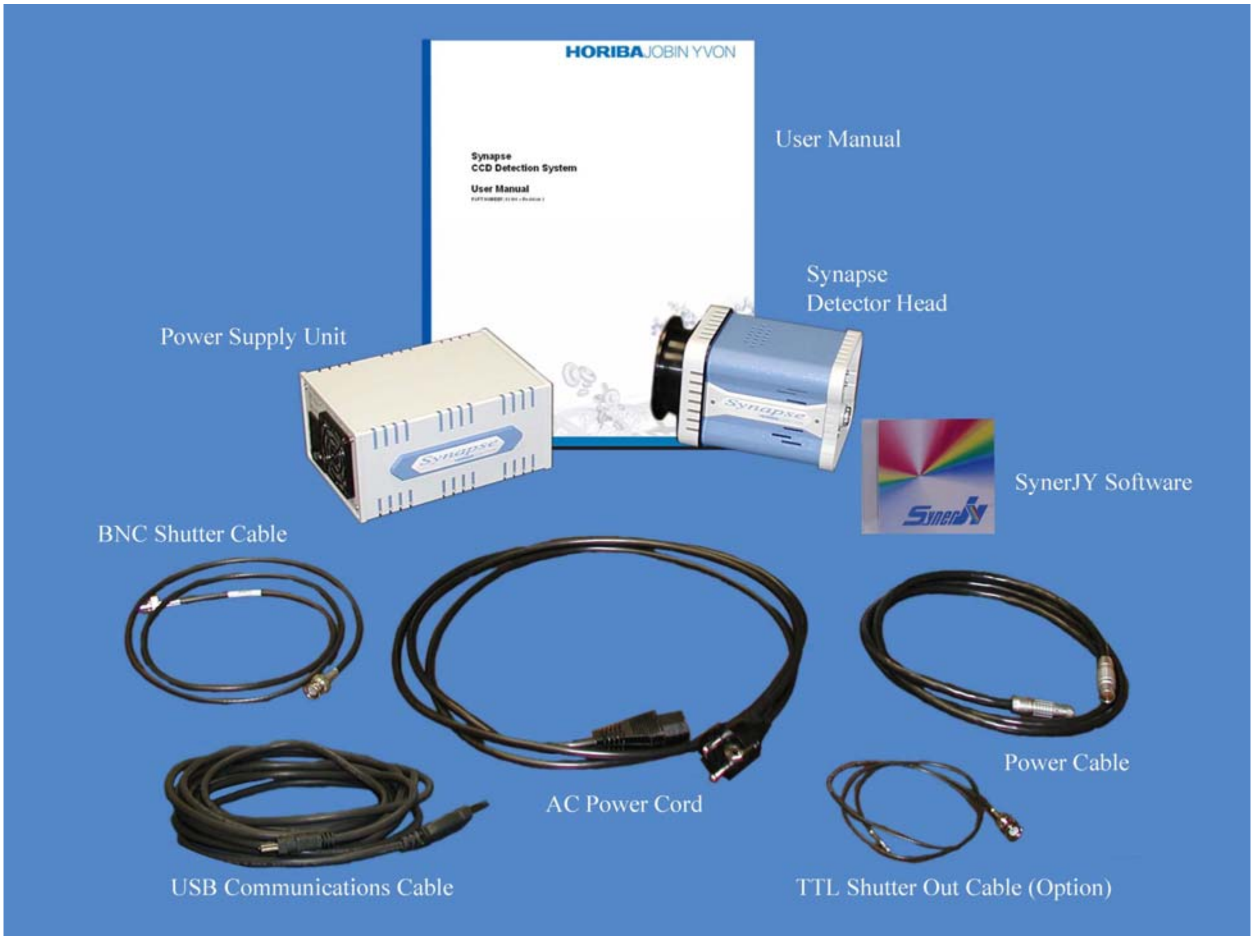


Figure 2. Typical Synapse System Components

Table III. Individual Components for the Synapse

Item #	Component Description		HORIBA Jobin Yvon Part Number
1	Synapse CCD Detector		CCD-XXXX-XXX-SYN
2	Power Supply Unit		354010
3	Shielded USB Communications Cable, A to B		980087
4	AC Power Cord	CEE 7/7 to CEE-22 (220 V)	98020
		NEMA 5-15 to CEE-22 (110 V)	98015
5	BNC Shutter Cable	4 ft (standard)	352470
		8 ft	30646
		2 ft	31936
6	Power Cable		400735
7	SynerJY Spectroscopic Application Software		CSW-SYNERJY
8	Synapse User Manual		81100

Installing SynerJY Application Software

Note: If using application software other than SynerJY, follow the installation procedure provided with that software.

1. Remove the SynerJY USB hardware key from your computer if it is already installed.
2. Start Windows if you have not already done so. Make sure all programs are closed.
3. Insert the CD labeled **SynerJY** into your CD-ROM drive. If Autorun is enabled installation will begin automatically. If Autorun is not enabled, execute the **Setup.exe** file by selecting **My Computer>SynerJY CD-ROM>Setup.exe**.
4. If you have a previous version of SynerJY installed, a question dialog box appears. Select **Yes** to uninstall the previous version.
5. The InstallShield Wizard dialog box appears. Click **Next** to display the License Agreement.
6. Read the License Agreement carefully, then select **Yes** to agree to the terms and conditions of the agreement. You must agree to install SynerJY.
7. Enter your name and the name of the company for which you work. Click **Next**.
8. Select a destination location to install SynerJY or click **Next** to accept the default location (**C:\Program Files\Jobin Yvon**) and continue the installation.
9. At the prompt, remove any additional hardware keys. Click **Next**.
10. Select a restart option; the two options are **Yes, I want to restart my computer now** or **No, I will restart my computer later.**
11. Remove the SynerJY CD from the CD-ROM drive then click **Finish**.

Note: If you choose to restart your computer later, you must restart it before running SynerJY as the computer must be restarted for the software to run properly. When your computer restarts, the InstallShield Wizard automatically opens the device configuration dialog box, which allows you to load or create a hardware configuration. You must insert the SynerJY hardware key into a free USB port of your computer to start SynerJY.

Mounting Synapse to a Spectrograph

Synapse array detectors can be fitted to most HORIBA Jobin Yvon or Spex spectrometers that are equipped with a spectrograph exit port. The detector must be mounted in the correct orientation in order to perform properly. The following is a standard procedure for mounting a Synapse detector to an iHR or MicroHR spectrograph. Other spectrograph models may require a different mounting orientation. Please contact HORIBA Jobin Yvon customer service if you need assistance mounting your Synapse to a spectrograph.

Synapse CCDs are shipped with the CCD flange already attached to the camera. The CCDs are focused and aligned at the factory and when installed in a spectrograph, using the procedure below, should be properly aligned and require no further adjustments. If using a spectrograph not manufactured by HORIBA Jobin Yvon, the flange will require mounting to the CCD. Mount the CCD/flange assembly to the spectrograph as follows:

1. Insert the tube of the CCD flange into the CCD port of the spectrograph. Make sure that the flange pin is aligned with the corresponding slot.
2. Push the flange into the spectrometer until it stops.
3. The flange will touch the focus wheel. Rotate the CCD clockwise until it stops.
4. Tighten the flange lock using a 2.5 mm allen key.

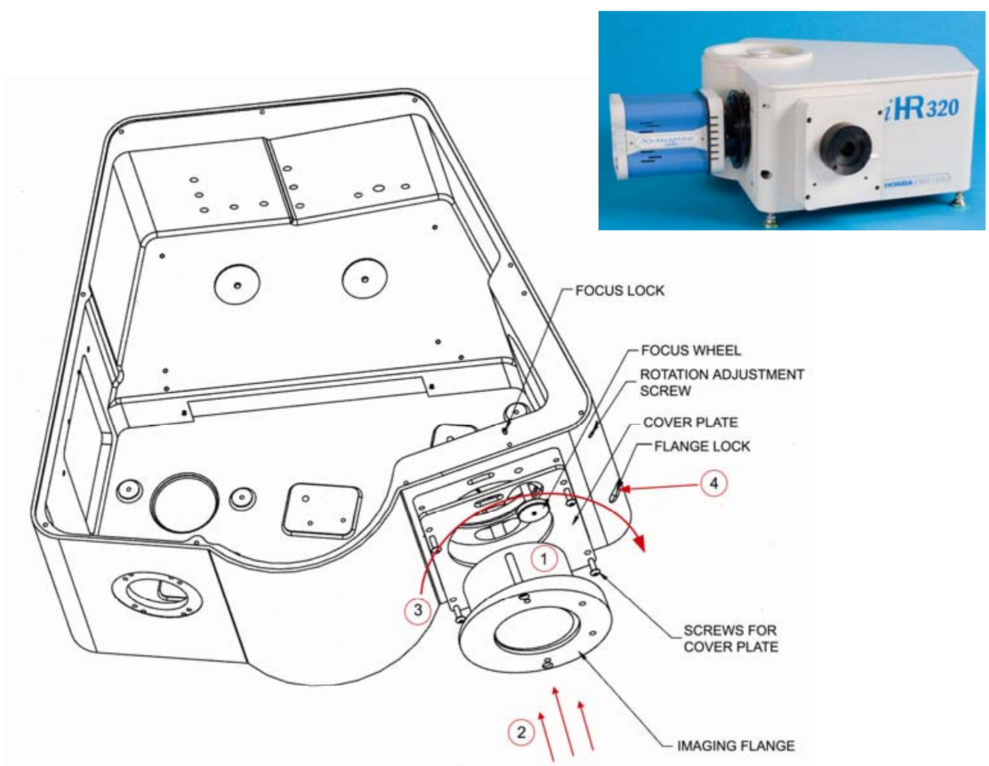


Figure 3. Flange Installation (Imaging flange pictured with iHR320 Spectrograph)

Connecting Electrical Interface Cables

1. Using the power cable (JY# 400735), connect the power supply unit (P/N 354010) to the 16-pin circular Lemo connector of the detector head.
2. Connect the female end of the power cord (P/N 98015 for 110 V or P/N 98020 for 220 V) to the power supply.

> **Note**: The Synapse detector head and power supply unit both incorporate a 16-pin Lemo connector, which only allows for a straight, spring loaded insertion push and pull action when respectively connecting and disconnecting the power cable.
>
> Never attempt to turn or rotate the Lemo connectors associated with the power cable during the attachment process to either the Synapse detector head or power supply unit, as this action could permanently damage said interface.

3. Plug the wall outlet end of the power cord into a properly grounded outlet to provide a chassis-to-earth ground.
4. Locate a USB 2.0 port on your computer and connect the USB communications cable (P/N 980076) (A end) to the computer.
5. Connect the other end of the USB cable (B end) to the USB 2.0 interface located on the back panel of the detector head.
6. Connect the BNC shutter cable to the BNC Shut port. Connect the remaining end of the BNC receptacle to the spectrograph.

> **Note**: The first time that the unit is connected to the computer, Windows® will detect a new USB device and automatically install the appropriate driver (see Chapter 4: Initial Power-up and Operation).

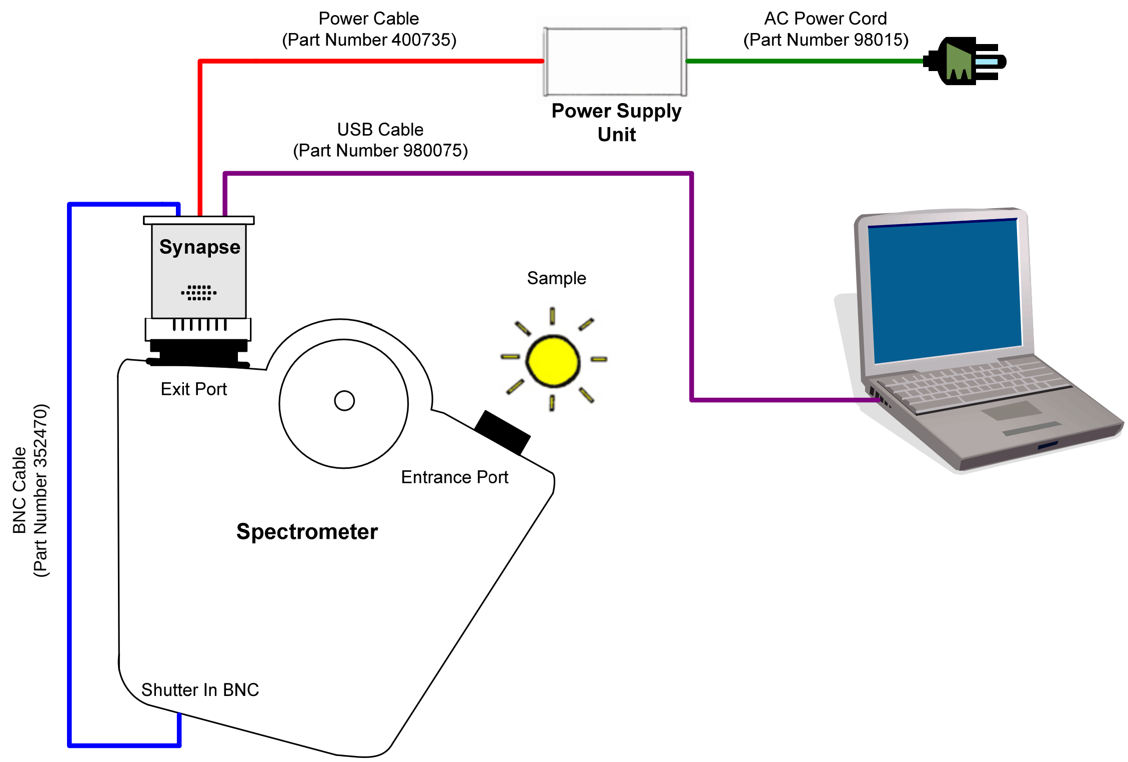


Figure 4. Typical Synapse Electrical Interconnect Scheme

Chapter 4: Initial Power-up and Operation

This chapter guides you through the steps necessary to initially power-up and successfully begin to acquire spectra with a Synapse system. In addition, detector head issues related to proper CCD focusing and alignment to a spectrograph are discussed in detail.

A brief summary of the available data acquisition modes is also provided.

Operation of Synapse is predominantly controlled by software, and as such, requires experimental setup and equipment configuration via SynerJY application software. Please refer to the *SynerJY Installation Guide* and Help File for information related to proper experiment set-up if needed.

To power-up and operate your Synapse, please follow the steps in the order listed below.

- Initial Power-up
- Configuring Hardware
- CCD Focus and Alignment on the Spectrograph
- Operation Modes

Initial Power-up

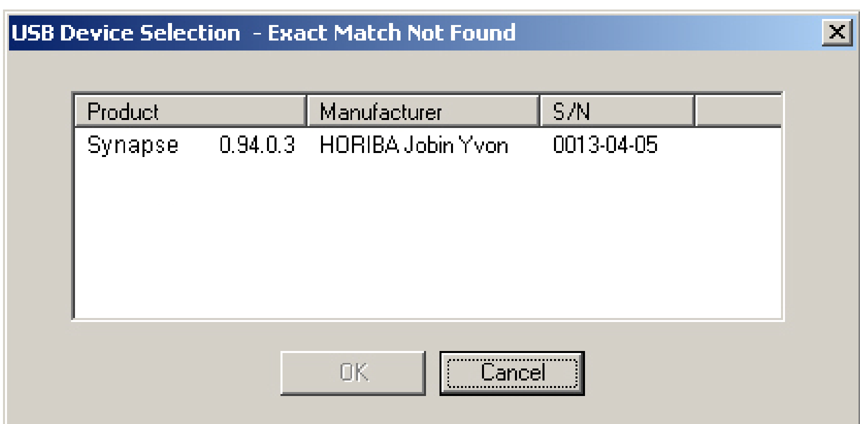
1. Check that all system cables interfacing to and from the overall detection system are properly connected.
2. Verify that the Synapse power supply unit, computer, spectrograph and any additional supporting equipment are connected properly to AC input power.
3. **Make sure that all software has been installed before the unit is turned on.**
4. Set the power switch on the back of the power supply to the **ON** (“l” symbol) position.
5. Once the power switch is activated, the LED located on the front panel of the Synapse power supply unit will illuminate green. The PWR LED located on the detector head will also illuminate green. The TEMP LED located on the detector head will illuminate yellow to indicate that cooling is taking place and will turn green once it reaches the set temperature.
6. The computer will recognize that a new USB device has been powered up and is connected to the computer.

7. The **New Found Hardware Wizard** screen opens. Click **Next**.

8. As Synapse's software is loaded, a warning that the software has not passed Windows Logo Testing appears. The software has been fully checked for compatibility issues by HORIBA Jobin Yvon and will not interfere with the correct operation of your system. Click **Continue Anyway**.

9. After the software installation is complete, click **Finish**.

10. The first time the Synapse detector is used, the following screen appears. Click on **Synapse….** to highlight the displayed text, then click **OK**. If more than one Synapse detector is listed, chose the correct one based on serial number.



11. Launch SynerJY or other application software and proceed to load or create the proper hardware configuration.

CCD Focus and Alignment on the Spectrograph

> **Note**: If your Synapse was delivered with a MicroHR or iHR spectrograph, focus and alignment have been performed at the factory. If your CCD was ordered separately or if you are experiencing difficulty, it is recommended that your follow this procedure.

MicoHR and iHR series spectrographs provide mechanisms for precise adjustment of the focus and rotational alignment of a CCD camera. The adjustments consist of the CCD focus wheel, the focus lock set screw, the CCD rotation adjustment screw, and the CCD flange lock. If mounting to other spectrograph models, consult your spectrometer manual to determine the correct mounting orientation. **Refer to Appendix C for a more detailed focus and alignment procedure using SynerJY software.**

Before starting this procedure, make sure that:

- Software is installed and running
- CCD detector head is properly mounted on the spectrograph
- CCD detector is cooled to the correct operating temperature

> **Note**: For instructions on mounting the Synapse CCD detector to a MicroHR or iHR spectrograph, see the "Installation of the CCD Camera" section of Chapter 3.

Preparing Focus and Alignment Mechanisms

1. Attach a spectral line source, such as a mercury lamp, to the instrument entrance slit. Consult the documentation provided with your lamp for proper mounting instructions. **Do not turn the lamp on.**

CAUTION

Your light source may emit high-intensity ultraviolet, visible, or infrared light. Exposure to these types of radiation, even reflected or diffused can result in serious, and sometimes irreversible, eye and skin injuries. When using a lamp, do not aim the light guide at anyone or look directly into to the light guide or optical ports of the instrument. Always wear protective goggles and gloves in conjunction with the light source.

2. Using a 2.5 mm allen key, loosen the M3 cap head screw on the flange lock by turning the allen key counter-clockwise. This screw is accessed through the flange lock hole in the side of the unit. Note that when the flange lock is loose, the CCD flange is free to slide in and out of the unit.
3. Using a 2 mm allen key, remove the M3 button head screws which secure the top cover of the unit and remove the top cover.
4. Using a 1.5 mm allen key, loosen the focus lock set screw (M3).
5. Replace the top cover.
6. The CCD focus wheel and rotation adjustment screw are free to move. The CCD focus wheel, touching the inside face of the CCD flange, acts as a focus stop for the CCD flange. The CCD rotation adjustment screw, touching the pin on the CCD flange, acts as a rotation stop for the CCD flange.

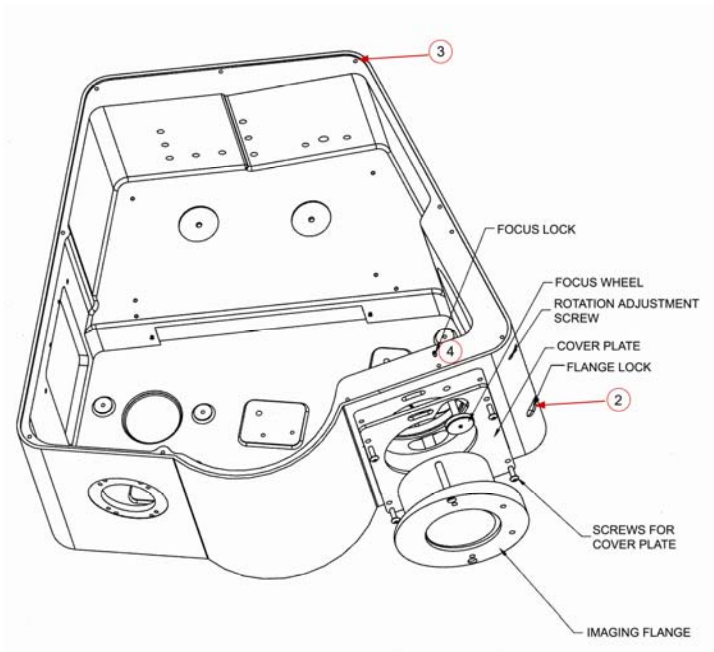


Figure 5. CCD Rotation and Adjustment Mechanisms

Synapse Focus and Alignment

1. Turn on the light source. Using the software, make the slit width as narrow as possible (~ 10 µm) on the detector. This will allow determination of the best focus.
2. Manually set the height limiter to 1 mm.
3. From the software, enter a reference wavelength (such as a Hg line at 546 nm).
4. Set the detector to Spectral Acquisition mode. Set the data to display as signal intensity (Y-axis) vs. pixel position (X-axis).
5. Set the Integration Time to 0.1 second or less, and run continuous spectral acquisition. While continuously running, adjust the Integration Time until the observed signal is approximately 40,000 counts.
6. View the spectra. A focused, aligned CCD will provide a distinct peak of large amplitude, generally symmetrical to the limits of the design of the spectrometer. The peak should be less than or equal to 3-5 pixels wide across the Full Width of Half the Maximum height (FWHM).

Excessive asymmetry of the peak is a sign that the slit image is not aligned to the pixel columns; diminished shape and magnitude are symptomatic of defocusing.

7. Stop the acquisition.
8. Using the software, divide the chip to five equal areas.
9. Run the experiment continuously at the initial reference wavelength.
10. When aligned, the 5 spectra will overlap but may not show similar intensity. Each spectrum should be 3-5 pixels wide at FWHM.
11. To adjust the focus of the CCD camera, rotate the focus wheel with your fingers to drive the CCD flange out from the body. To bring the camera focus in, it is necessary to hold the camera against the wheel while rotating the focus wheel.
12. To adjust the alignment (rotation) of the CCD camera, insert a 1.5 mm allen key into the hole in the side of the unit to engage the CCD rotation adjustment set screw. Turning the screw into the body (clockwise) will push against the pin on the CCD flange rotating the camera. To rotate in the opposite direction, you need to turn the camera against the rotation adjustment screw while turning the screw counter-clockwise.
13. When the focus and alignment of the camera are properly set, tighten the flange lock to clamp the CCD flange in position.
14. To lock the focus wheel in its current position, turn off the light source, remove the top cover of the spectrograph and tighten the focus lock set screw. If it is necessary to remove the CCD for some reason, simply loosen the flange lock set screw and remove the CCD. This Quick-Align CCD adapter mechanism allows easy replacement of the CCD with minimal realignment.

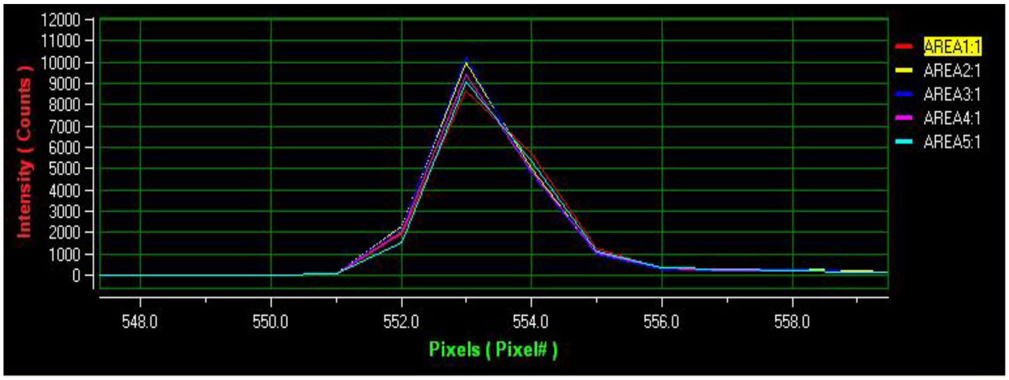


Figure 6. Example of a Focused and Aligned CCD

Modes of Data Acquisition

The Synapse CCD detection system allows for a variety of data acquisition modes. The correct acquisition mode will depend on the experiment being performed and the data format required by the user. Data acquisition modes and experimental parameters are selected by the end-user via SynerJY software.

This section contains a brief description of the acquisition modes currently supported by Synapse systems. Also provided, is a description of acquisition parameters required to run each type of experiment. The following page provides a detailed description of the acquisition parameters. Refer to Appendix C for detailed procedures about conducting experiments with SynerJY.

CCD Position

In a CCD Position experiment, the spectrometer is set to a specific grating position by the software. When the experiment is run, the CCD collects data only from the wavelengths of light that reach the CCD detector. Each column of the CCD is then mapped to a single wavelength. This data can be viewed as spectral or image data.

Spectral Data

Spectral experiments can be defined to have multiple areas of interest on the CCD array. In such experiments, each area produces a single spectrum.

CCD Position spectral data is obtained when the signal is binned or summed along each column in a selected area during acquisition. The resulting data set is a spectrum with a signal intensity value for each column of pixels or group of binned columns. The intensities are then recorded and displayed according to the user's preference as either a function of pixel number or as a function of the wavelength assigned to each pixel.

Required Parameters: Areas, X-Binning, Integration Time, Accumulations, Gain and ADC Speed.

Image Data

Image experiments can be defined to have multiple areas of interest on the CCD. In such experiments, each area results in a separate image.

CCD Position image data is collected by recording the signal of each individual pixel or binned group of pixels on the CCD array. The resulting set of data is a 3-Dimensional plot of Intensity as a function of X position and Y Position. For the Synapse CCD Detection system, the X axis corresponds to wavelength and data can be recorded and displayed on the X axis as a function of pixels or wavelength. The Y axis represents the height position along the entrance slit of the spectrometer.

Required Parameters: Areas, X-Binning, Y-Binning, Integration Time, Accumulations, Gain and ADC Speed.

CCD Range

In a CCD Range experiment, the spectrometer is set to acquire data throughout a wavelength range which is selected by the end-user via SynerJY software. When the experiment is run, the spectrometer's grating rotates to collect data in sections, with each section representing a different wavelength range. There is a small overlap at the edges of each section. Once all data is collected by the detector, the individual sections are combined to produce a single spectrum.

Required Parameters: Areas, X-Binning, Integration Time, Accumulations, Gain and ADC Speed.

> **Note**: CCD Range mode experiments are only supported under SynerJY software. For more information, please refer to the SynerJY software manual.

Triggering

External Triggers may be used to synchronize experiments. Triggers can be implemented to start an experiment sequence or can be used on each individual accumulation. Please refer to Chapter 5 for a more detailed discussion on triggering with the Synapse CCD detection system.

Acquisition Mode Parameters

- **Areas –** definition of the active sections of the CCD detector. Signals that encounter sections of the CCD that are not part of an active area are not recorded. Once an area is specified, the area definitions refer to the number of areas and the size of the areas.

- **X Binning** – number of columns combined to form a single data point. By combining columns, a greater signal level can be detected; however, this results in a decrease in resolution.

- **Y Binning** – number of rows combined to form a single data point. By combining rows, a greater signal level can be detected; however, this results in a decrease in resolution.

- **Integration Time** – amount of time the CCD is exposed to light and acquires data.

- **Accumulations** – number of repetitions for which the detector collects data and averages the results to obtain a better signal-to-noise ratio.

- **Gain** – equates the least significant bit (LSB) of the Synapse 16-bit ADC architecture to an appropriate electron level (see Chapter 8: Gain Selections).

- **ADC Speed selection** – sets the rate at which the data is read off the CCD detector. For maximum signal to noise, the ADC speed should be set to 20 kHz. For maximum frame rates, the ADC speed selection should be set to 1 MHz.

- **Time Interval** – the elapsed time between the start of one accumulation to the start of the next accumulation. The Time Interval, Integration Time and Readout Time of the CCD detector have the following relationship:

$$t_{\text{interval}} \geq t_{\text{integration}} + t_{\text{read}}$$

Chapter 5: Triggering

Synapse provides a versatile platform with respect to synchronizing to the end-user's experimental equipment. The detector provides two TTL level I/O signals, via SMB type connectors on the rear of the unit, for monitoring and/or control of various user accessories.

To avoid connection errors, a male gender SMB is utilized for the TTL input signal associated with the External Trigger Input function, while its female gender counterpart provides for the detection system's TTL output signal capability. It should be noted that this TTL output signal functionality provides the end-user with the ability to select, via SynerJY software, one of three available signals for use in the experiment as follows:

TTL Output Options:

SHUTTER

The SHUTTER signal provides status with respect to shutter operation and is activated during the interval when the CCD is being exposed to light.

START EXPERIMENT

The START EXPERIMENT signal indicates the start of an experiment. Upon receipt of a "Start Acquisition" command, this output goes to its active state after completion of its present CCD array cleaning cycle. For time-based operation, this output remains active until all spectra have been taken and then returns to its inactive state.

EXT TRIGGER READY

The EXT TRIGGER READY signal is applicable to the detection system's External Trigger mode of operation and is used to indicate when the system has completed the current spectral acquisition (i.e. exposure and readout) and is ready to begin subsequent acquisitions.

> **Note**: Each selected output signal can also be configured, via software, for a specific polarity where the active state can be either a logic high (5V) or logic low (0V) to meet the needs of the experiment.

Refer to Appendix C for additional information regarding enabling/configuring these TTL level I/O signals.

Synchronized Triggering to an External Event

Acquisition of image or spectral data can be initiated and synchronized to an external system event by using the trigger input capability of the Synapse's TTL Input. This TTL input line uses edge triggering, which is user programmable via software control to recognize positive or negative edge triggered events. This external triggering capability can be used to activate the start of each experiment, as well as, to initiate each acquisition of an experiment involving multi-acquisitions.

It should be noted that once the detector has recognized a valid external trigger pulse, any and all subsequent activity on this external input will be ignored until the integration period and CCD readout time have completed for the acquisition at hand.

For experiments involving multiple acquisitions, the allowable repetition rate (t rep rate) associated with this external triggering function is governed by the sum of the CCD expose time (t expose) and subsequent data processing readout time (t readout) as follows:

$$t_{\text{rep rate}} \geq t_{\text{expose}} + t_{\text{readout}}$$

Figure 7, on the following page, illustrates the relative timing associated with an external trigger input waveform and the subsequent expose (i.e. shutter) and readout timing information available via the TTL Output. Figure 7 depicts an externally triggered single acquisition experiment using positive edge triggering for the Trigger Input signal and active high logic levels (5 V) all output signals shown.

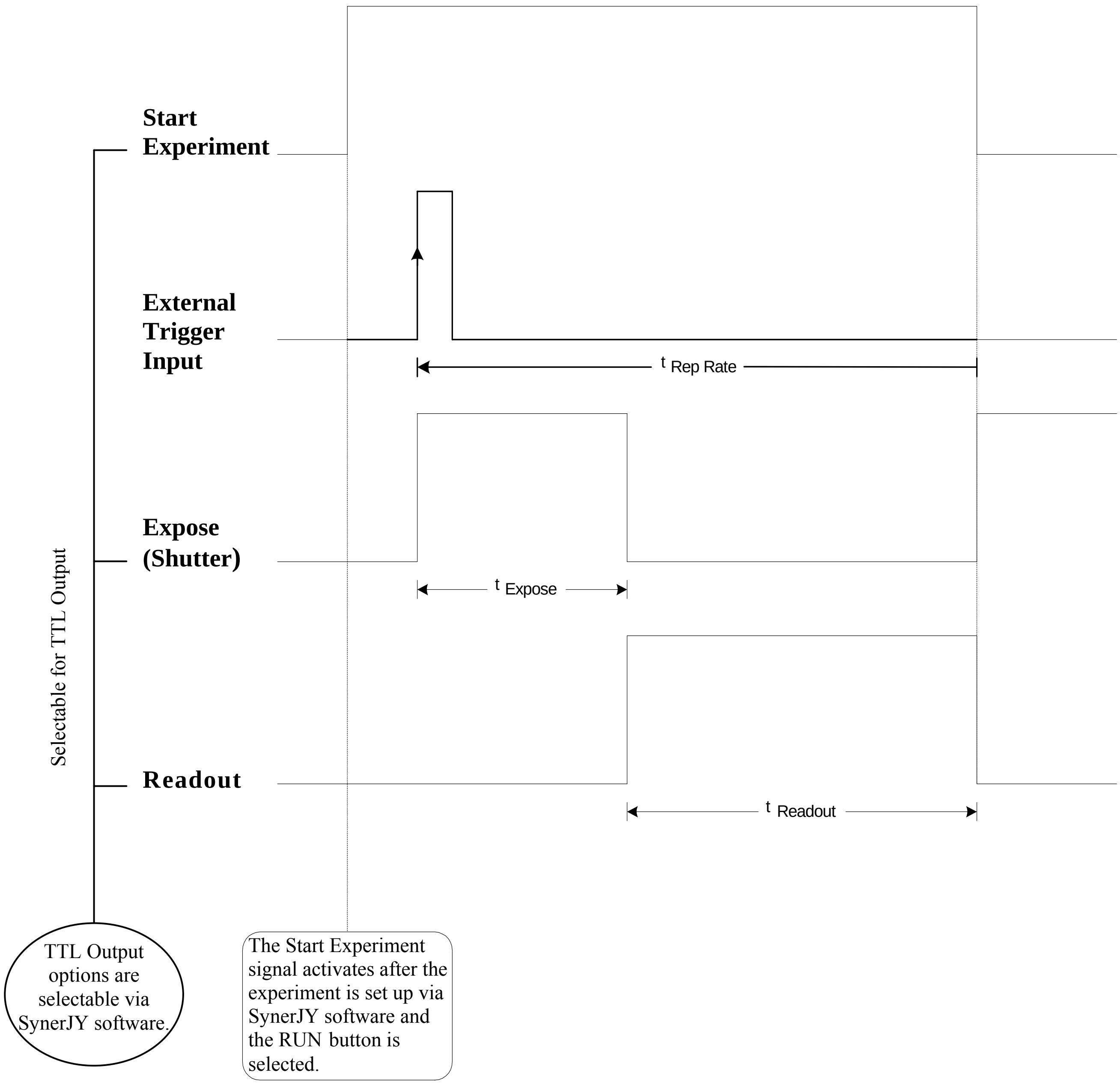


Figure 7. Timing Diagram for an Externally Triggered Single Acquisition Experiment Using Positive Edge Triggering

Figure 8 below illustrates the relative timing associated with another externally triggered experiment. Here, the experiment is set-up for a multi-accumulation acquisition of 2 spectra using a negative edge triggered Trigger Input signal and active low logic levels (0 V) for all TTL output signals available to the end-user.

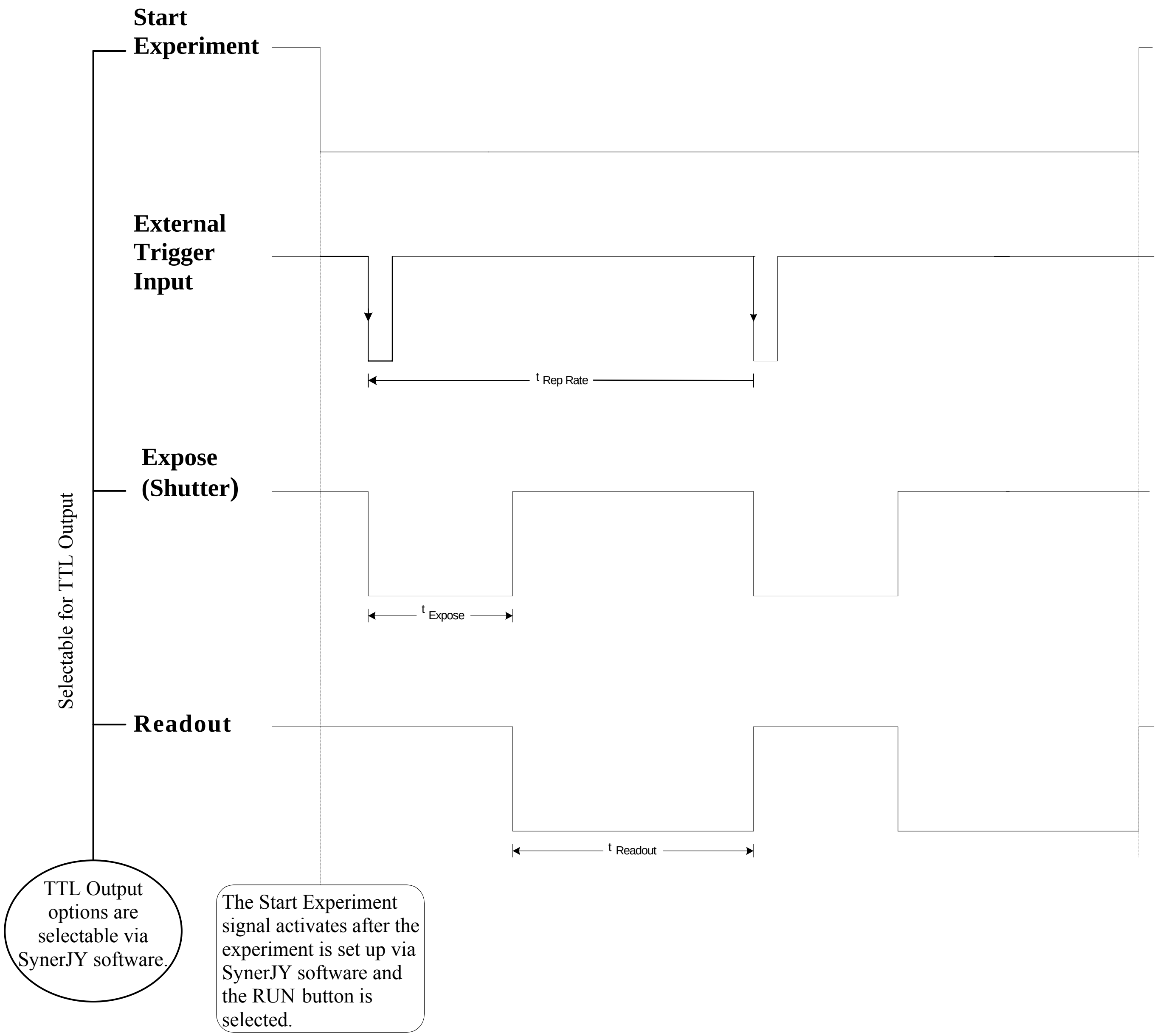


Figure 8. Timing Diagram for an Externally Triggered Multi-accumulation Acquisition Using Negative Edge

Chapter 6: Auxiliary Analog Input

The Auxiliary Analog Input port (AUX IN) is designed to measure a voltage or current signal and can be used as an independent data acquisition channel or as a reference channel to correct CCD acquisitions for power fluctuations in an excitation source.

The AUX IN port accepts signals from a single channel detector up to +/- 10 V in **Voltage** mode or up to +/- 10 µA in **Current** mode via an SMA connector. The AUX IN input channel incorporates programmable gain capability (1/10/100/1000) to adjust for signal sensitivity as required.

Normalization (Reference)

The Normalization mode of the AUX IN port allows the system to correct acquired data for some external reference signal. For example, a silicon detector might be used to monitor the power of an excitation lamp or laser. The final data can be adjusted for the power fluctuations in the lamp/laser by dividing the data by the reference signal. The Synapse CCD automates this process by measuring the AUX IN signal during integration time of the CCD. Signal values from the AUX IN port are averaged over the CCD integration time and the CCD data is divided by the average value from the AUX IN Port.

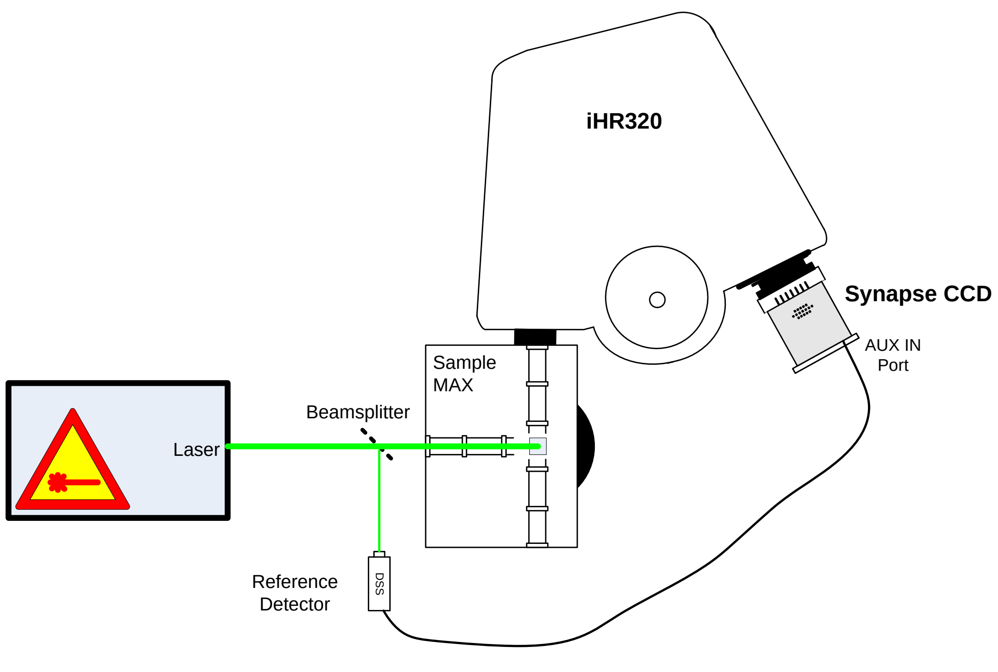
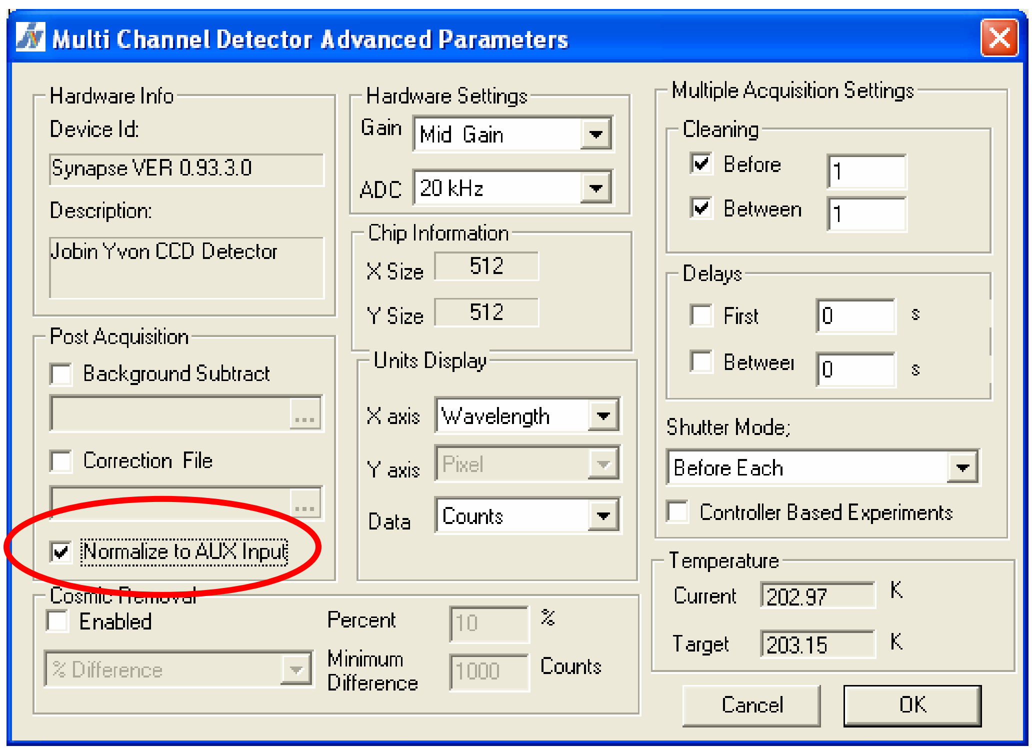


Figure 9. Typical Configuration for Normalization using Synapse AUX IN Port

To use the AUX port as a reference channel:

1. Start SynerJY and open the **Experiment Setup** screen.
2. Click the **Detectors icon** from the **General** tab. Click the **Active** check box to activate the detector. Select the **Acquisition Mode** and **Experiment Type** and enter any additional experiment parameters.
3. Click the **Advanced** button to view the **Multi Channel Detector Advanced Parameters** screen. Select the **Normalize to AUX Input** check box to enable Normalization (uncheck the box to disable this feature). Click **OK** to close the window.
4. Click **Run** to start the experiment.

5. When the Normalize function is enabled, the Synapse CCD will collect data from the CCD and collect a reference value from the AUX IN port. The CCD data will then be divided by the value collected from the AUX IN port and displayed on the screen.



Independent Data Acquisition

The AUX IN port can also be used as an independent data acquisition channel for voltage or current signals. This can be used to extend the wavelength range of a spectrometer system by adding an InGaAs detector to the side port of a spectrometer without having to purchase additional electronics. The system, used as a spectrograph with a CCD, can cover 200 nm to 1100 nm and as a scanning monochromator with an InGaAs detector can cover from 800 nm to 1700 nm. The Synapse CCD's AUX IN port averages the data from the InGaAs detector over the specified integration time.

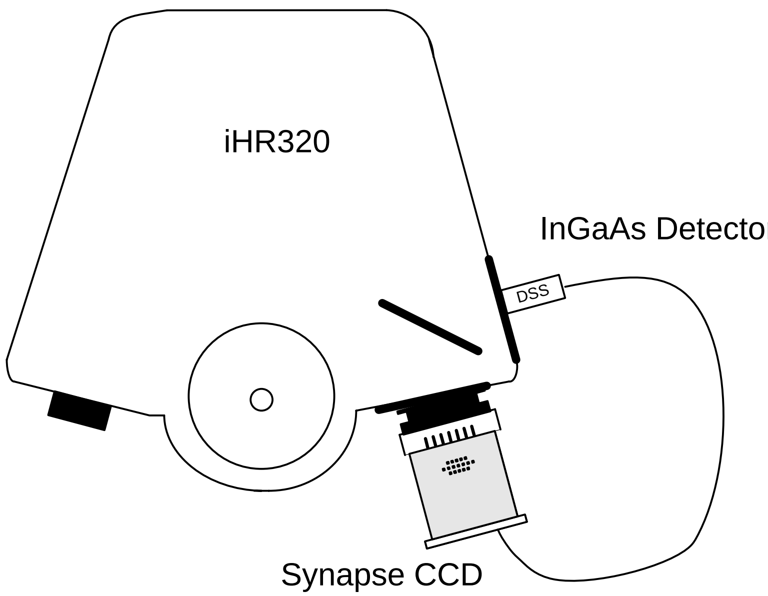
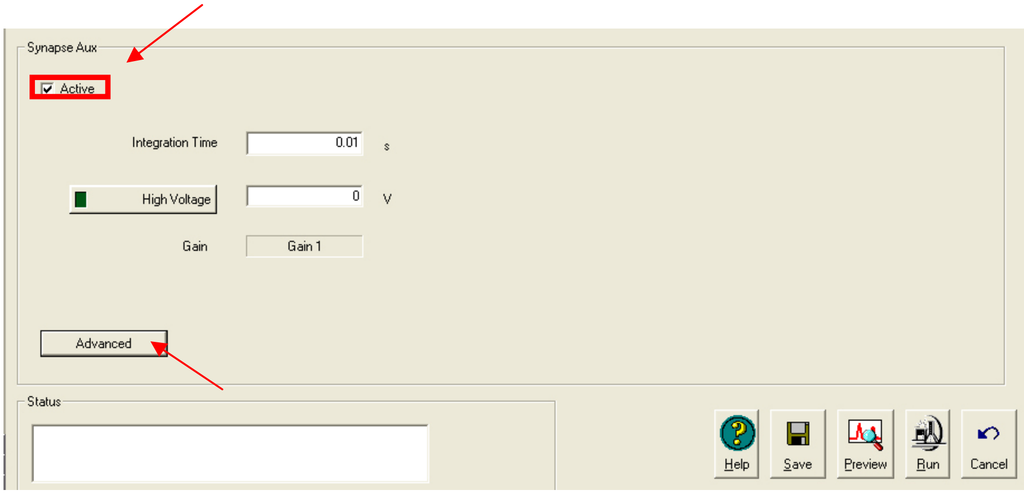


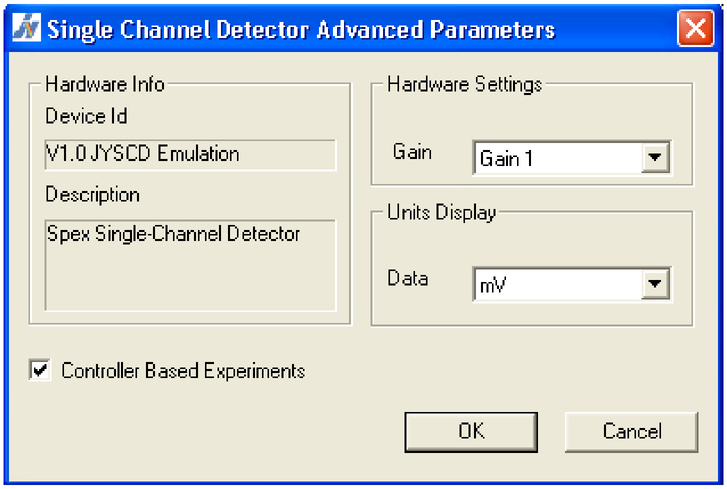
Figure 10. Typical Configuration for Independent Data Acquisition using Synapse AUX IN Port

To use the AUX IN as an independent data acquisition channel:

1. Make sure the detector is configured in SynerJY or the SDK as a **Single Channel Detector** (refer to the hardware configuration procedures of your software documentation).
2. Start SynerJY and open the **Experiment Setup** screen.
3. Select the Hardware Configuration that has the AUX IN configured as a **Single Channel Detector**.
4. The AUX IN port appears as an option in the detectors list in **Experiment Setup** and **Data Preview**; click the **Active** check box to activate it.



5. Select the **Experiment Type** and enter any additional experiment parameters.
6. Click the **Advanced** button to view the **Single Channel Detector Advanced Parameters** screen.
7. Select the proper **Units** and **Gain** settings. Click **OK** to close the window.



8. Click **Run** to start the experiment.

Configuring for Voltage and Current Modes

To switch Auxiliary Analog Input operation modes, two separate **Single Channel Detector** configurations (one for **Voltage** and one for **Current**) need to be created in the hardware configuration, both connected to the Synapse. When one of these detectors is initialized, the Synapse will be configured as the specified voltage or current device.

Chapter 7: Temperature Control

Synapse monitors and regulates the array's set point temperature via its thermostatic control circuitry. For optimum array performance with respect to dark current, quantum efficiency and signal-to-noise ratio, Synapse typically provides a default cooling set point temperature -70 °C (203 K).

Array temperature setability is provided in steps of ± 0.1 °C resolution. From a temperature stability standpoint, once thermal equilibrium has been reached, the detector's cooler power and thermostat control circuitry ensure that the array temperature will not drift more that 0.1 °C from the commanded value.

Chapter 8: Detector System Component Description

The primary components making up a Synapse CCD detection system are:

- CCD Detector Head
- Power Supply Unit
- SynerJY Application Software

In addition to the primary components listed above, all Synapse CCD detection systems are provided with one mechanical shutter and an associated interface cable. A number of shutter options are available for interfacing to various HORIBA Jobin Yvon spectrometers.

Synapse CCD Detector Head

All Synapse detectors use high quality scientific grade CCD array formats specifically designed for spectroscopic applications. Choosing the most appropriate format for your detection system is dependent on the intended spectroscopic application.

Detector Head Cooling

High-performance thermoelectric cooling allows the detectors to achieve temperatures better than -70 °C (203 K) without the use of LN_2, providing very low dark current, and allowing for good signal-to-noise ratio and long integration times.

The Synapse detector head employs a multi-stage Peltier cooling device that is thermally coupled to the CCD array inside an evacuated chamber. Heat is drawn away from the array's surface as current is passed through the Peltier device. The heat transfer process continues in succession thru the Peltier stages to a heat spreader located on the atmospheric side of the detector, where it is then air-cooled via an accessory fan.

The detector heads can run continuously at their set operating temperature of -70 °C (system default setting) without maintenance. It should be noted that air-cooled detector heads, require freely circulating, ambient room temperature air to cool and maintain the array's operating set temperature. Failure to stay within the ambient operating conditions specified herein may cause an increase in array temperature, resulting in higher dark current.

Synapse detector heads incorporate a temperature sensor that continuously monitors the Peltier's hot side sink temperature. This protective circuitry prevents possible damage to the array by disabling the cooler power supply when its internal, preset temperature is exceeded due to faults such as inadvertent restricted airflow. Under such a fault condition, the TEMP LED located on the rear of the detector will transition from a GREEN illumination state (indicating that thermoelectric cooling is functioning properly and has reached its set temperature) to a non-illuminated state (indicating a fault/no cooling).

Detector Head Chamber and Cooling Effectiveness

All Synapse CCD detector heads contain a high-vacuum front end which houses the CCD sensor, as well as, the Peltier cooling element. The design includes a single-window element, made of fused silica or magnesium fluoride for deep-UV response. All materials in the forward chamber are selected to be of UHV grade materials and techniques, to minimize outgassing and maximize emissivity, thus offering the highest cooling efficiency. Each Synapse CCD system is evacuated at the factory on a dedicated production line, using permanent, hard metal seals. There is no user maintenance required.

The cooling of the CCD sensor relies on the quality of the vacuum. Any degradation of the vacuum, such as by fracturing of the window due to physical damage, is evidenced by the inability of the Synapse CCD to reach operating temperature. The cooling system status is displayed on the detector's rear interface, as a bi-color TEMP LED. While in cooldown mode, the TEMP LED will illuminate as yellow, indicating that the Peltier device is powered and cooling the sensor. Once the temperature setpoint is reached, the system will enter closed-loop mode, and the TEMP LED will turn green, indicating a temperature lock at the desired setpoint.

If the Synapse CCD is damaged, and the vacuum is compromised, the TEMP status LED will remain yellow, indicating that the system cannot reach the desired setpoint. Please contact the factory for advice in the event that the system cannot reach the setpoint within 30 minutes from power up, or if physical damage to the instrument is suspected. It is not advisable to operate the Synapse CCD in a compromised vacuum state, as potential moisture entering the head will condense and then freeze within the Peltier stack, causing further damage. In addition, moisture in the CCD area could cause corrosion of sensitive areas including the CCD sensor itself.

Detector Head Electrical Interfaces

Synapse detector heads provide the following external interface connections for proper system operation:

- Power
- USB 2.0 Communication
- Shutter
- TTL Input
- TTL Output
- Auxiliary Analog Port
- External I^2C
- Temperature Status LED
- Power Status LED

Figure 11. Detector Head Electrical Interfaces

Power

The power receptacle utilizes a 16-pin circular Lemo connector to provide the required DC input power to the detector head and interfaces to the power supply unit via the detection system's power cable (JY# 400735).

USB 2.0

The USB 2.0 port accepts the standard USB-B end of the USB communications cable, allowing true USB 2.0 "plug-n-play" communications between the Synapse and the operating computer.

Shutter

The shutter drive interface is a BNC receptacle that accepts the shutter cable, connecting the detector to the spectrograph shutter. This interface is intended to drive a single electro-mechanical shutter having the following characteristics:

Coil resistance:	12 ohms
Pulsed voltage to open:	+60 V DC
Hold voltage:	+5 V DC
Operating frequency:	40 Hz maximum rep rate

TTL Input/Output

Two TTL level Input/Output signals are available for monitoring and/or control of various user accessories via SMB connectors located on the rear of the detector. To avoid connection errors, a male gender SMB is utilized for the TTL input signal associated with the External Trigger Input function, while its female gender counterpart provides for the detection system's TTL output signal capability. It should be noted that that the digital logic associated with Synapse's TTL output connector provides a multiplexed pathway, making three signals available to the end-user (selectable via SynerJY software). A brief description of the functionality associated with each TTL interface follows:

TTL Input (Trigger Input)

The TTL Input connector provides for the Trigger In function. Selection of the "External Trigger" mode of operation enables Synapse to synchronize data acquisition to external events. This input provides for either positive or negative edge triggering and is selected by the user via software.

TTL Output (3 options programmable under SynerJY):

SHUTTER

The digital SHUTTER signal provides status with respect to shutter operation and is activated during the interval when the CCD is being exposed to light.

START EXPERIMENT

The START EXPERIMENT signal indicates the start of an experiment. Upon receipt of a "Start Acquisition" command, this output goes to its active state after completion of its

present CCD array cleaning cycle. For time based operation, this output remains active until all spectra have been taken and then returns to its inactive state.

EXT TRIGGER READY

The EXT TRIGGER READY signal is applicable to the detection system's External Trigger mode of operation and is used to indicate when the system has completed the current spectral acquisition (i.e. exposure and readout) and is ready to begin subsequent acquisitions

> **Note**: The output signal can also be configured, via software, for a specific polarity where the active state can be either a logic high (5V) or logic low (0V) to meet the needs of the experiment. Refer to Appendix C for additional information regarding enabling/configuring these TTL level I/O signals.

Auxiliary Analog Port

The Auxiliary Analog Input port is used for accommodating either a current or voltage single channel detector. This external interface utilizes an SMA connector and can be used as an independent data acquisition channel or as a reference channel to correct CCD acquisitions for power fluctuations in an excitation source.

From a system's perspective, the AUX IN port is software programmable to operate in either a voltage or current mode and correspondingly accepts signals from up to +/- 10 V in Voltage mode or up to +/- 10 µA in Current mode. In addition, this independent analog channel incorporates programmable gain capability (1/10/100/1000) to adjust for signal sensitivity as required.

External I^2C

An external Inter-Integrated Circuit (I^2C) bus interface is provided to allow Synapse to communicate with end-user specific, slave I^2C devices when required. This two-wire, synchronous, serial interface supports bi-directional data transfers up to 100 kbits/sec in standard mode and 400 kbits/sec in fast mode.

In terms of an end-user's experimental setup, this two-wire serial interface can be used to control: (a) stepper motors associated with the end-user's optics (i.e. filter wheel), (b) serial digital-to-analog (DAC) converters that vary control voltages associated with light source intensities and / or (c) serial E^2PROMs that store pertinent system configuration data.

Additionally, this interface provides fused +5 V or +3.3 V DC power (factory default setting at +5 V DC) for instances where customer specific slave I^2C devices require bias power as well (Fuse rating = 200 mA max). Figure 12 specifies pin-out definition for this detector system function. It should be noted that utilization of this communication interface is only supported thru the use of HORIBA Jobin Yvon's Software Development Kit (SDK).

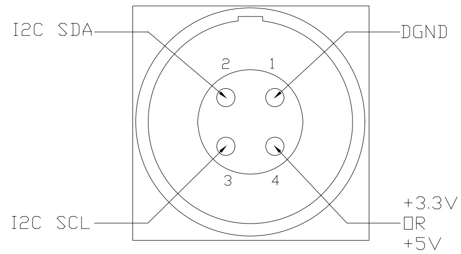


Figure 12. External I^2C Connector Pin Out (viewed looking at rear of detector)

Power LED

Illumination of the PWR LED indicates that the unit has been powered.

Temperature Status LED

The TEMP status LED is a bi-color LED that illuminates YELLOW upon power-up to indicate that the detector is cooling and has not reached its proper operating temperature. This LED illuminates GREEN once the detector has reached its set temperature. The LED will not illuminate without the application of power to the detector head or if a cooling fault exists.

Pixel Processing / Data Acquisition Modes of Operation

The sophisticated and compact design of the Synapse detector contains all of the electronics necessary to read and control the CCD sensor. The detector's high technology architecture is targeted for optimum performance and high-speed spectral/image acquisition and offers end-users two different modes of acquisition selectable via software control:

- 20 kHz Slow Scan Acquisition Mode
- 1 MHz Fast Scan Acquisition Mode

A brief description follows for both pixel processing modes of operation.

20 kHz Slow Scan Acquisition Mode

For extreme spectroscopic applications requiring unprecedented sensitivity, Synapse offers end-users the lowest noise and highest dynamic range possible by processing pixel information at a 20 kHz ADC rate selectable thru the SynerJY application software. HORIBA Jobin Yvon's proprietary low noise 16-bit analog circuitry contributes negligibly to the overall system noise, which is dominated by the CCD sensor's read noise typically in the 3-4 electron range.

1 MHz Fast Scan Acquisition Mode

In addition to the 20 kHz slow scan mode of acquisition, the Synapse platform also provides end-users with the ability to process 16-bit pixel information at a 1 MHz rate. This high-speed mode of operation is useful in quickly resolving focus and alignment issues, as well as, acquiring data fast. Typical system noise for the 1 MHz scientific grade CCDs currently being offered by HORIBA Jobin Yvon is better than 20 electrons rms, and takes into account the system's electronics noise and the read noise of the sensor itself**.**

> **Note:** Specific Synapse noise values are chip dependent and will vary depending on the selected CCD architecture and pixel size, as well as the respective readout amplifier performance.

Gain Selections

Synapse provides the end-user with 16-bit pixel processing capability that includes three gain options selectable via SynerJY software as specified in Table IV below. For each gain setting, typical system level transfer function numbers are provided in electrons per ADC count based on the typical CCD amplifier response (uV / e-) for each sensor offering.

Table IV. Synapse Gain Options Versus Sensor Offerings

CCD Sensor	Pixel Format	Pixel Size	Gain Setting	Typical System Transfer Function (e- / ADC Cnt)
E2V CCD30	1024 x 256	26 µm sq	High Sensitivity	1.40
			Best Dynamic Range	2.80
			High Light	18.70
E2V CCD42	2048 X 512	13.5 µm sq	High Sensitivity	1.06
			Best Dynamic Range	2.12
			High Light	7.06
E2V CCD77	512 X 512	24 µm sq	High Sensitivity	0.88
			Best Dynamic Range	2.94
			High Light	11.77

With the Synapse's flexible gain setting capability, low light level applications would take advantage of the High Sensitivity mode gain setting, while experiments involving elevated photon flux levels would benefit the most from the High Light gain setting.

Note: Calibration data is provided with each Synapse CCD detection system, defining the transfer function in electrons/count for the incorporated CCD sensor for each available gain setting.

A brief discussion of each gain setting mode associated with the Synapse CCD Detection system follows:

High Sensitivity Mode

For low light level applications, most end-users are willing to trade off dynamic range performance for increased sensitivity so that even the smallest photonic occurrence can be detected. Utilization of this High Sensitivity mode, from a statistical averaging point of view, allows small variations in light level to be detected even on a 1 e- scale.

It should also be noted that operating in this high gain mode allows end-users with medium light applications to acquire the same photon flux information two to three times faster (depending on the selected CCD) when compared to using the Best Dynamic Range gain setting mode.

Best Dynamic Range Mode

For low to medium light applications, where ratioing of photon peak information is crucial, the end-user is recommended to use the Best Dynamic Range gain setting. This medium gain mode of operation allows end-users to have good sensitivity, as well as, the capability to collect larger photon levels without compromising linearity.

It should also be noted that selection of this gain mode allows end-users with high light applications to acquire the same photon flux information four to six times faster (depending on the selected CCD) when compared to using the High Light gain setting mode.

High Light Mode

The High Light gain setting mode of operation enables the end-user to see the complete full well capability of the sensor, including the CCD’s transition from the linear to saturated region.

System Noise

From a system perspective, total system noise is typically specified in electrons RMS at a minimum integration time (i.e. Tint = 0 sec). This CCD detection system parameter is comprised from three major sources:

- CCD Read noise
- Electronics noise
- CCD Dark Current Shot noise

Calculation of the detection system's total baseline noise is arrived at using the following equation:

$$\text{Total System Noise} = \sqrt{[\text{CCD Read Noise}]^2 + [\text{Electronics Noise}]^2 + [\text{Dark Shot Noise}]^2}$$

For the purposes of this manual, system noise contributions from the CCD's dark current shot noise or noise contributions from the signal itself (i.e. shot noise) are ignored. In general, thermoelectrically cooled CCD detection systems, as exemplified by the Synapse CCD Detection System, typically have negligible dark current especially when considering minimum integration times, and as such, contribute fractions of an electron to this figure of merit system parameter. Thus, total system noise is primarily influenced by the associated read noise of the selected CCD's output amplifier structure, as well as, the detection system's electronics.

For the Synapse CCD Detection System, typical system noise figures range between 3 to 5 electron RMS (i.e. 1 sigma), and are largely dependent on the specific sensor used as compared to the system's electronics. It should be noted that the Synapse CCD Detection System incorporates the lowest noise front-end analog architecture in an effort not to compromise the system's baseline noise or effective dynamic range. To illustrate the dependency and impact the CCD's read noise has on the overall noise floor within the Synapse architecture, system noise is calculated below for an E2V CCD30 device operating at a 20 kHz pixel processing rate:

E2V CCD30 Read Noise	=	3.28 e-
Synapse Electronics Noise	=	1.20 e-
Dark Shot Noise	=	0 (ignored)

$$\text{Total System Noise} \quad = \quad \sqrt{[3.28\ \text{e-}]^2 + [1.2\ \text{e-}]^2 + [0]^2} \quad = \quad 3.5\ \text{e- RMS}$$

As illustrated by the above example, the Synapse CCD Detection System's total noise is limited by the sensor's read noise with minimal contribution and/or impact from the electronics suite.

It should be noted that from a user's visual prospective, this 3 to 5 electron RMS value only signifies a statistical measurement where any individual "dark" scan can encompass pixel readouts with peak-peak electron variation of approximately 5.5 times the stated

RMS value (≈ 19.25 e- pk-pk). Figure 13 below illustrates a typical raw baseline noise scan for a Synapse detector configured in the “High Sensitivity” gain mode under dark conditions with the calculated resultant 3.5 e- RMS noise.

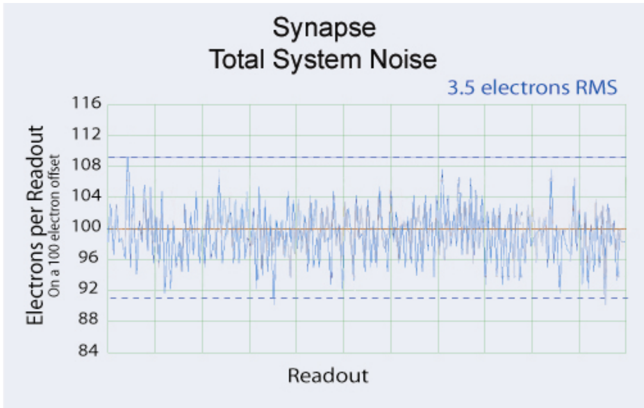


Figure 13. Typical Dark/Noise Scan for the Synapse CCD Detection System in High Sensitivity Mode

Built-In-Test Diagnostic Capability

All Synapse detectors incorporate built-in-test (BIT) circuitry that provides a comprehensive level of testability to support the manufacturing process, as well as, field maintainability. This BIT circuitry provides automated test capability via resident diagnostic firmware routines to ensure the operational health of the detector and to validate the detection system's performance.

CCD Hardware Binning Control

Adding neighboring CCD pixels together to form a single pixel is a technique known as binning. Binning can be accomplished in hardware during the readout process or through software intervention (SynerJY) after the data has been collected from the CCD. This binning process can be exercised at the hardware level in both the horizontal (x) and vertical (y) directions for multiple areas of interest in a given readout as previously set-up in the SynerJY software**.**

Figure 14 on the following page illustrates a basic 2 x 2 binning operation on a 4 x 4 CCD array. This successful binning operation consists of two vertical clocking operations followed by two horizontal clocking transfers that effectively shift the summed pixel information into the output amplifier's storage node prior to pixel readout and digitization. This "super pixel," once digitized, actually represents four pixels of the CCD array.

It should be noted that binning does reduce resolution capability; however, it increases sensitivity and improves (i.e. lowers) the overall CCD readout time. End-users are cautioned that there is a limit to the effectiveness of hardware binning as a result of the horizontal serial shift register and output node not having infinite capacity to store charge. This physical limitation is best exemplified for applications that have a very small signal superimposed on a large background. In practice, the pixels associated with the horizontal register have twice the full well capacity of their light sensitive counterparts, while the output node usually can hold four times that of the photosensitive area. Thus, experiments where the summed charge exceeds either the full well capability of the horizontal shift register and/or the output node will be lost from a data processing point of view.

CCD Exposure Control

Synapse precisely controls CCD exposure time using a 1 kHz expose clock frequency that provides flexible integration times of 0.001 to 4,294,967.296 sec (49.71 days). End-users can set the desired exposure time with SynerJY application software.

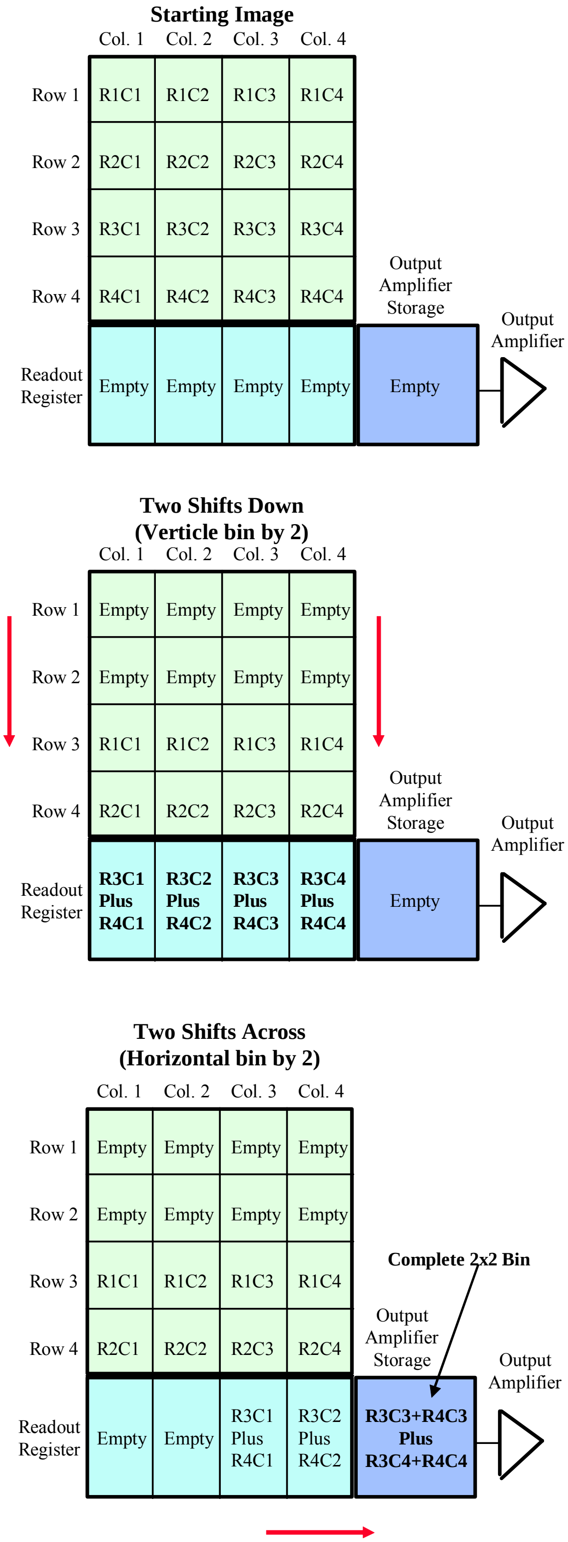


Figure 14. Illustration of 2 x 2 Binning Operation on a 4 x 4 CCD Array

Synapse Power Supply Unit

The Synapse power supply unit accepts universal AC single-phase input power over the range of 85 to 264 VAC with an associated line frequency range of 47 to 63 Hz and develops the necessary DC bias voltages required by the system to operate properly.

This compact and efficient unit is also responsible for generating the thermo-electric power used by the detector head's peltier in an effort to remove / isolate the detrimental effects of this circuitry with respect to noise, power dissipation and heat from the overall Synapse detector head assembly. In addition, the power supply unit has provisions to incorporate an optional power shutter drive circuit for instances where an electro-mechanical shutter will be required for the end-user's application.

The power supply unit contains a fan to help cool the enclosed electronics and maintain optimum system performance. Care should be taken to ensure that the ventilation slots on power supply unit are free from obstruction in order to maintain an adequate level of air flow for proper operation. In addition, the unit incorporates a dust cover to filter out debris and air-borne particulate matter from the air intake path. Depending on the end-user's environment, it is recommended that the dust cover filter be periodically removed and cleaned at a minimum of once every six months (procedures for removing and cleaning the dust cover are found in the "General Maintenance" section of Chapter 2).

A brief description of the power supply unit's functional circuit elements follow:

Integrated TE Power Supply

The power supply unit incorporates resident circuitry that provides clean, filtered thermoelectric (TE) cooling power for use by the Synapse detector head. This TE cooling circuitry monitors and regulates the detector array's set point temperature with less than ± 0.1 °C drift.

This versatile TE cooling circuitry eliminates the need for any additional external power source requirements with respect to peltier cooling.

Integrated Power Shutter Drive Circuitry (optional)

The power supply unit incorporates an optional power shutter circuit capable of driving a single electro-mechanical shutter with the following characteristics:

Coil resistance:	12 ohms
Pulsed voltage to open:	+60 V DC
Hold voltage:	+5 V DC
Operating frequency:	40 Hz maximum rep rate

Power Supply Unit Electrical Interfaces

The Synapse power supply unit provides the following external interface connections for proper system operation:

- AC Input Power
- Detector Head Power
- Power Status LED

Figure 15. Power Supply Unit Electrical Interfaces

AC Input Power

The Synapse power supply unit operates from universal AC single-phase input power over the range of 85 to 264 V AC with a line frequency of 47 to 63 Hz. This AC input power is applied to a two-pole fusing power entry module located on the rear panel of the power supply unit. This module incorporates two 5 x 20 mm IEC approved, 2.0 A, 250 V, ceramic slow blow fuses (Cooper Bussmann Part# BK / GDC-2A or equivalent) to protect against line disturbances/anomalies outside the system's normal operating power range.

Detector Head Power

The detector head power receptacle, located on the front panel of the power supply unit, utilizes a 16-pin circular Lemo connector to provide the required DC input power to the detector head via the detection system's power cable (JY# 400735).

Power LED

Illumination of the PWR LED, located on the front panel of the power supply unit, indicates that the unit has been powered.

Software

HORIBA Jobin Yvon's SynerJY software facilitates the operation of your Synapse CCD detection system. This software, designed for ease-of-use, allows for complete control over every aspect of your spectroscopic system. Using SynerJY, you can conduct and define experiments, establish preferred settings, adjust hardware parameters, and evaluate and analyze data. In addition, the software is equipped to automate repetitive functions and permits the user to define and save experimental parameters. SynerJY offers a variety of ways to view data, allowing for quick and powerful interpretation. Please refer to the documentation provided with the software for user instructions.

Shutter

A variety of electro-mechanical shutters is available from HORIBA Jobin Yvon for use with your Synapse CCD. Depending on the model type, the shutter may be mounted inside or outside of the spectrograph. Table V (on the following page) lists some commonly used spectrographs and the shutters with which they are compatible.

Refer to the appropriate spectrograph manual for detailed installation instructions. Contact the HORIBA Jobin Yvon Service Department for shutter installation assistance (refer to the Service Policy).

Table V. Shutter Models

Spectrograph	Location	Shutter Part #	BNC Cable Part #
Auto MicroHR	External	MHRA	980078 (BNC to SMA)
iHR320/550	Front Side	MSH-ICF MSH-ICS	352470, 4 ft Standard Cable Depending on the system configuration, one of the following may be provided in place of the standard BNC shutter cable: 30646, 8 ft 31936, 2 ft
Triax180/190	Front Only	MSL-TSHCCD	
Triax320 Triax550	Front (axial) Side (lateral) alone Side (lateral) both	227MCD MSL-TSHCCD MSL-TSCCD2	
500M 750M 1000M 1250M	Front (axial) Side (lateral) alone Side (lateral) both	1425MCD 1425MCD-B 1425MCD-C	
750I	Front (axial)	227MCD	
CP140 CP200	External Only	23009030	
HR460	Front (axial)	23024630	
HR640	External Only	23009030	
THR1000	External Only	23009030	
THR1500	Contact Factory		
U1000	Contact Factory		
1403 1404	Front (axial)	1425MCD	
1870 1877	Front (axial)	1425MCD	

Chapter 9: Powering Down and Disassembly of the System

This chapter provides the necessary steps to methodically and safely power down your Synapse CCD detection system. In addition, information is presented that details the proper disassembly process for your detection system.

Power Down Procedure

- Exit the application software.
- Set the power switch on the back of the power supply to the **OFF** (“O” symbol) position.

> **Note**: It is safe to leave the Synapse detector un-powered and mounted to the spectrograph as long as all system cables interfacing to the detector remain securely connected.

Disassembly of the Detection System

In instances where the experiment set-up needs to be disassembled, the following steps should be taken in the order specified:

1. Exit the application software.
2. Set the power switch on the back of the power supply to the **OFF** (“O” symbol) position.
3. Disconnect the power cable interfacing between the power supply unit (P/N 354010) and the detector head.
4. Disconnect the BNC shutter cable interfacing between the spectrograph and the detector.

> **Note**: The HORIBA Jobin Yvon warranty on Synapse does not cover damage to the sensor or the system’s electronics that arises as a result of improper handling including the effects of Electrostatic Discharge (ESD).

5. Remove the USB 2.0 communications cable (P/N 980076) from the back panel of the detector head.

6. Loosen the flange lock and/ or set screw of the spectrograph (mounting is dependent on spectrograph model). Carefully remove the Synapse detector head from the spectrograph, pulling the detector towards you, out of the mount.
7. Unplug the AC power cord.

> **Note**: By adjusting only the flange lock of iHR and MicroHR series spectrographs, the CCD should be able to be reinstalled with minimal realignment as the focus and alignment mechanisms remain locked in place.

Chapter 10: Optimization and Troubleshooting

Following installation, some applications may require special attention in order to obtain optimal system performance. The system optimization and troubleshooting tips below have been provided to help the end-user maximize experimental results and troubleshoot potential problems.

Optical Optimization

The best way to increase the signal to noise ratio of a measurement is to increase signal strength at the detector by increasing optical power at the source or by increasing the integration time of the detector.

In cases where this is not possible, additional optical signal can usually be coupled into the system by minimizing the losses in the optical coupling from the source to the sample and/or from the sample to the spectrograph entrance slit. Checking the coupling optics for correct alignment and focus will often increase the signal level.

Incorrect f/# matching may cause stray light inside the spectrometer and be collected by the detector. Use correctly aligned and focused f/# matching optics to eliminate this possibility. For more information on f/# matching and coupling optics, please refer to *The Optics of Spectroscopy*, www.jobinyvon.com/usadivisions/oos/index.htm.

Stray light entering the spectrometer system through methods other than the entrance slit may interfere with the measurement. Reduce the possibility of stray light by securing all covers and closing all unused entrance or exit ports. When running any experiments, turn off all unnecessary room lights, including computer monitors.

Spatial Optimization

Often the optical signal of interest that is imaged on to the array occupies only part of the total array area. Sections of the array that are not illuminated will only add noise to the measurement. Taking advantage of the Area selection capabilities of Synapse, select a reduced portion of the CCD active area and reduce the dark signal and associated noise from the unused area. Susceptibility to cosmic rays will be reduced proportionately as well.

The best way to match the portion where the signal is located is to acquire a full-chip image of the signal. With the image, the area can be easily defined to just include the section of the CCD that is illuminated. If the actual signal is too weak to be seen in an image, increase the integration time or try to approximate the signal using the exact same collection optical setup, but substitute a brighter signal. Refer to your software manual for instructions on defining the active area(s).

Reducing the Number of Conversions

Each time an analog to digital conversion is made, some read noise is introduced. For spectra that are imaged as essentially vertical slit images on the array, the pixels illuminated in their vertical columns can be binned into superpixels, to be combined before conversion to data points. Likewise, when spectral resolution is not a limiting factor, the signals can also be horizontally binned into two-dimensional superpixels. The limit on this is that the combined signal intensity for the most intense superpixel should not exceed the ADC dynamic range. However, when signal levels in some pixels are at or near the saturation level, acquiring a series of spectra using integrations of shorter duration and summing them digitally provides a means to avoid saturation. Please refer to your software manual for instructions on setting up binning.

Environmental Noise Reduction

Because of the extreme low internal noise characteristics of the liquid nitrogen and thermo-electrically cooled sensors, precautions to minimize noise pickup from external sources is recommended.

Although shielded, the detector head and cables can still be sensitive to strong electromagnetic fields. For best results, the detection system should be isolated from devices generating such fields. In instances where external field sources may be hampering the detection system's optimum performance, HORIBA Jobin Yvon recommends the following:

- Electromagnetic interference (EMI) from a variety of sources may be picked up by the detection system's sensitive analog conditioning circuitry. Try isolating any other apparatus suspected to be a noise source by turning it off while monitoring the CCD signal in real time. Typical sources of EMI are high power lasers, vacuum pumps, and computer monitors. If possible, connect offending equipment to power sources separate from the detector controller and re-route cables away from interfering devices.

- Note that the room lights may radiate EMI based on the (50 or 60 Hz) power line frequency. A battery-powered flashlight will not.

- If turning off the spectrometer power switch reduces noise, rearrange power connections to be sure the spectrometer, source, and detector are tied to the same ground and, if possible, the same power circuit.

- In extreme cases, such as working with or around high powered pulsed lasers or other high energy apparatus, it may be helpful to construct RFI / EMI shields or cages to contain the noise at its source, or to isolate the detection system from the noise. In these cases, colleagues who are working with a similar apparatus may be your best resource for noise control suggestions.

Cooling

If the detector starts to exhibit higher than normal dark current levels in the same controlled experimental set-up, one of the following problems may have occurred:

- The cable connections between the power supply unit and detector may need to be secured.

- Physical damage, such as fracturing of the window, may have caused vacuum degradation. The cooling of the CCD sensor relies on the quality of the vacuum (refer to the "Detector Head and Chamber Cooling Effectiveness" section of Chapter 8). If the Synapse CCD is damaged and the vacuum is compromised, the TEMP status LED will remain yellow, indicating that the system cannot reach the desired setpoint. Please contact the factory for advice in the event that the system cannot reach the setpoint within 30 minutes from power up or if physical damage to the instrument is suspected.

Shutter

If the shutter should fail to actuate, verify that all cables are correctly connected. Contact HORIBA Jobin Yvon for further assistance.

Power Interruption

If power is interrupted, restart the system.

Software Cannot Recognize Hardware Configuration

- The system's software or firmware configuration matches the actual hardware configuration. Refer to the software documentation for more information on creating, editing, or loading a hardware configuration.
- The USB 2.0 port of your computer is working properly.
- If you have selected an appropriate hardware configuration for your system and a device is still not found during initialization, verify that all cables are correctly connected and that power is turned on.

Unit Fails to Turn On

If the unit fails to turn on, check that:

- The power cord is connected to the power supply unit.
- The power cord is plugged into a live outlet.
- The connector of the power supply unit is securely connected to the Synpase power interface.

Appendix A: Dimensional Drawings

Note: Dimensions are in inches (mm).

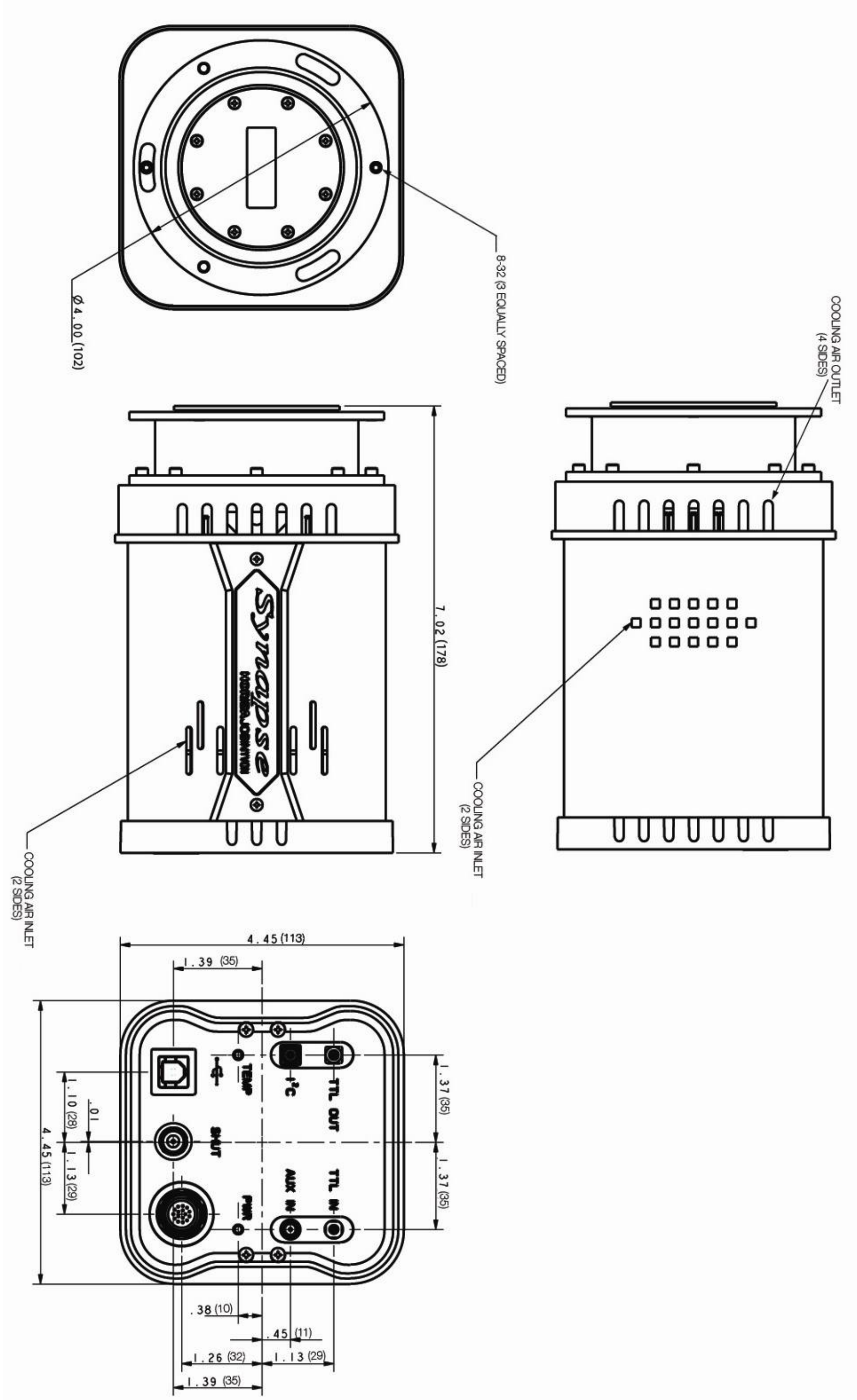


Figure 16. Synapse Detector Head

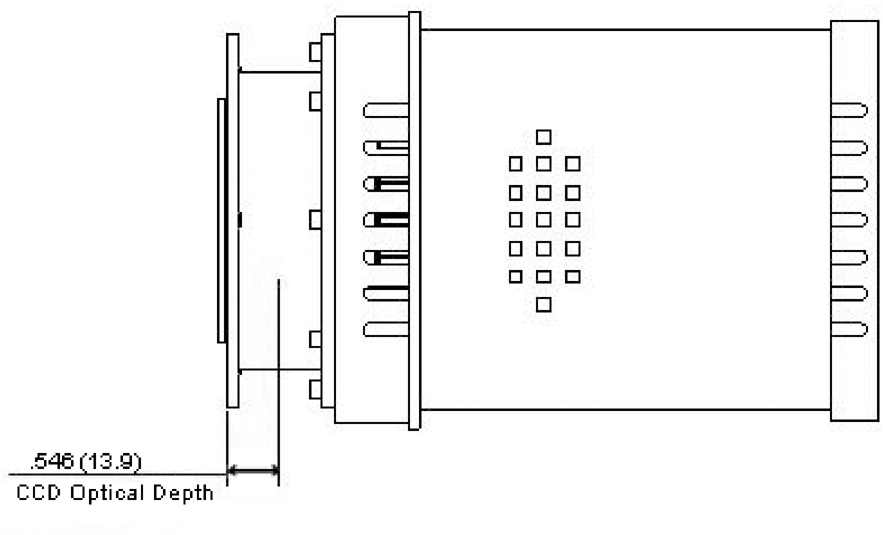


Figure 17. Distance from Focal Plane to CCD Chip

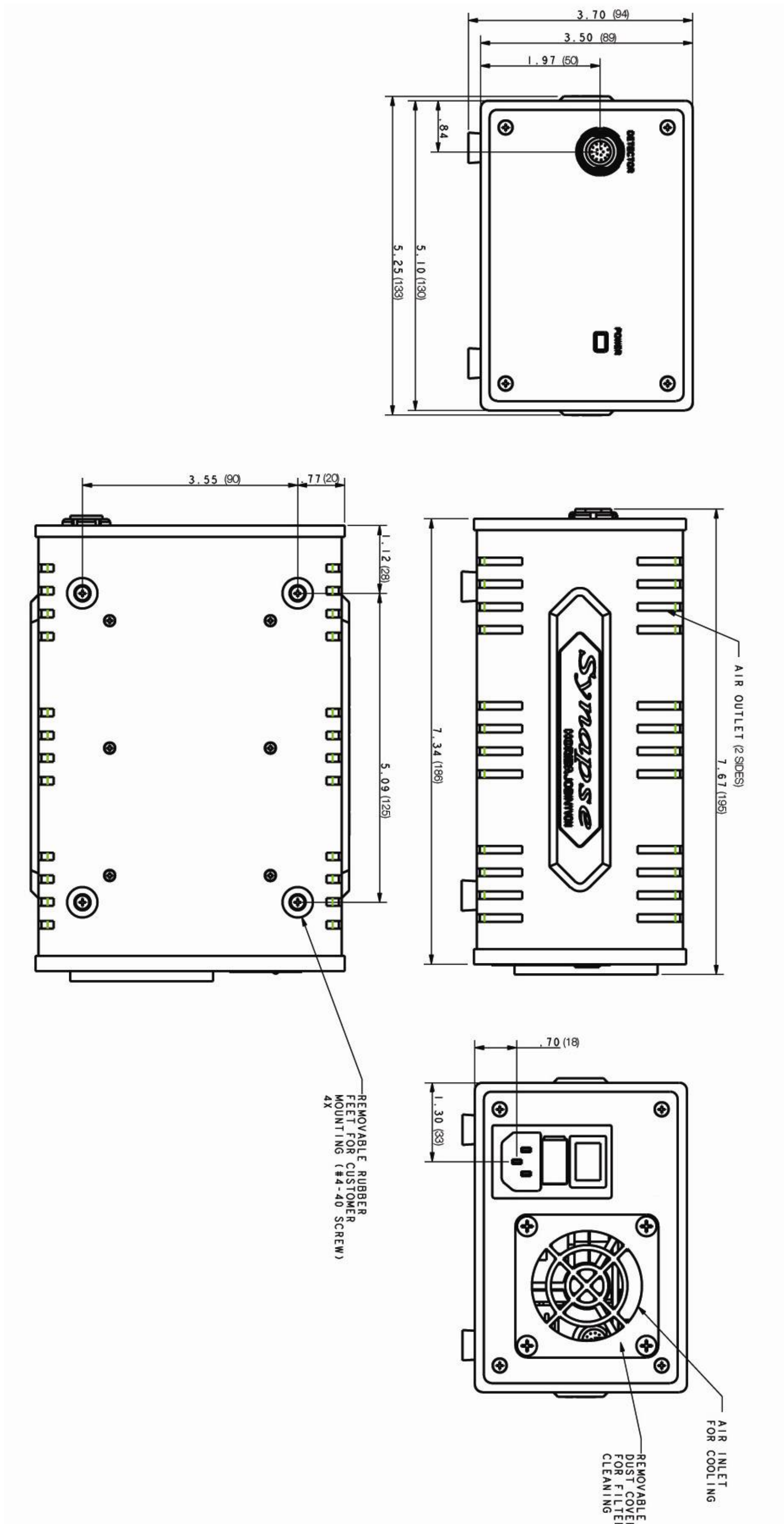


Figure 18. Synapse Power Supply Unit

Appendix B: CE Compliance Information

Declaration of Conformity

Manufacturer:	HORIBA Jobin Yvon
Address:	3880 Park Avenue Edison, NJ 08820 USA
Product Name:	Synapse CCD Camera System
Model Number:	CCD-XXXX-XXX-SYN

Conforms to the following Standards:

Safety:	IEC 60950-1: 2005
EMC:	IEC 61326: 2002 (Emissions & Immunity)

Supplementary Information

The product herewith complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC.

The CE marking has been affixed on the device according to Article 10 of the EMC Directive 8/336/EEC.

The technical file and documentation are on file with HORIBA Jobin Yvon Inc.

Nicholas Vezard, Vice-President

HORIBA Jobin Yvon

Edison, NJ 08820

USA

June 30, 2006

Table VI. Applicable CE Compliance Tests and Standards

Tests	Standards
Emissions, Radiated/Conducted	CISPR 11:2004 Class A
Radiated Immunity	IEC 61000-4-3: 2006
Conducted Immunity	IEC 61000-4-6: 2006
Electrical Fast Transients	IEC 61000-4-4: 2004
Electrostatic Discharge	IEC 61000-4-2: 2001
Voltage Interruptions	IEC 61000-4-11: 2004
Surge Immunity	IEC 61000-4-5: 2005
Magnetic Field Immunity	IEC 61000-4-8: 2001
Harmonics	EN 61000-3-2: 2005
Flicker	EN 61000-3-3: 2005
Safety	IEC 60950-1: 2005

Appendix C: Performing Routine Procedures with SynerJY

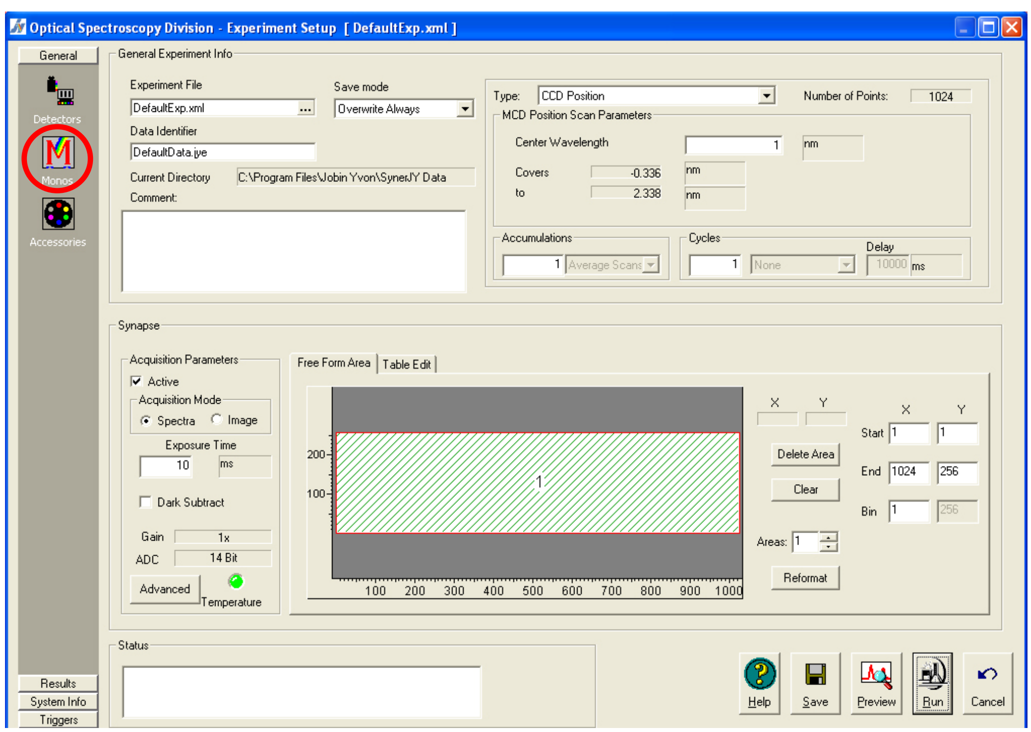
CCD Focus and Alignment on the Spectrograph

1. Attach a spectral line source, such as a mercury lamp, to the instrument entrance slit. Consult the documentation provided with your lamp for proper mounting instructions.

CAUTION

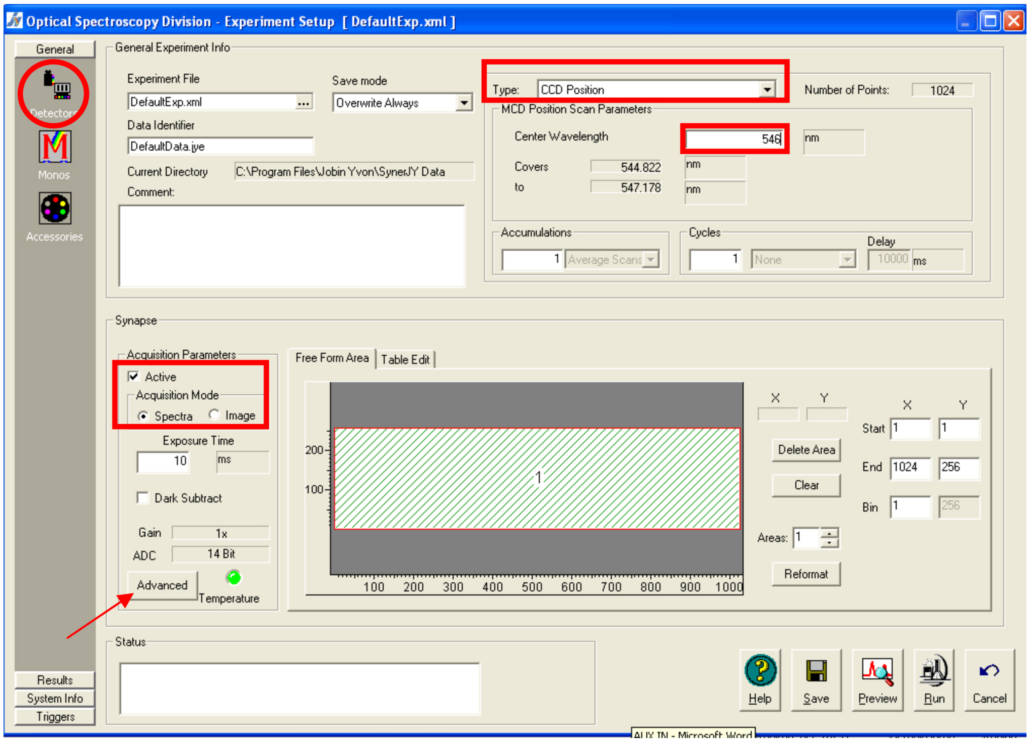
Your light source may emit high-intensity ultraviolet, visible, or infrared light. Exposure to these types of radiation, even reflected or diffused can result in serious, and sometimes irreversible, eye and skin injuries. When using a lamp, do not aim the light guide at anyone or look directly into to the light guide or optical ports of the instrument. Always wear protective goggles and gloves in conjunction with the light source.

2. Start SynerJY. In **Experiment Setup**; select **Monos** from the **General** tab.



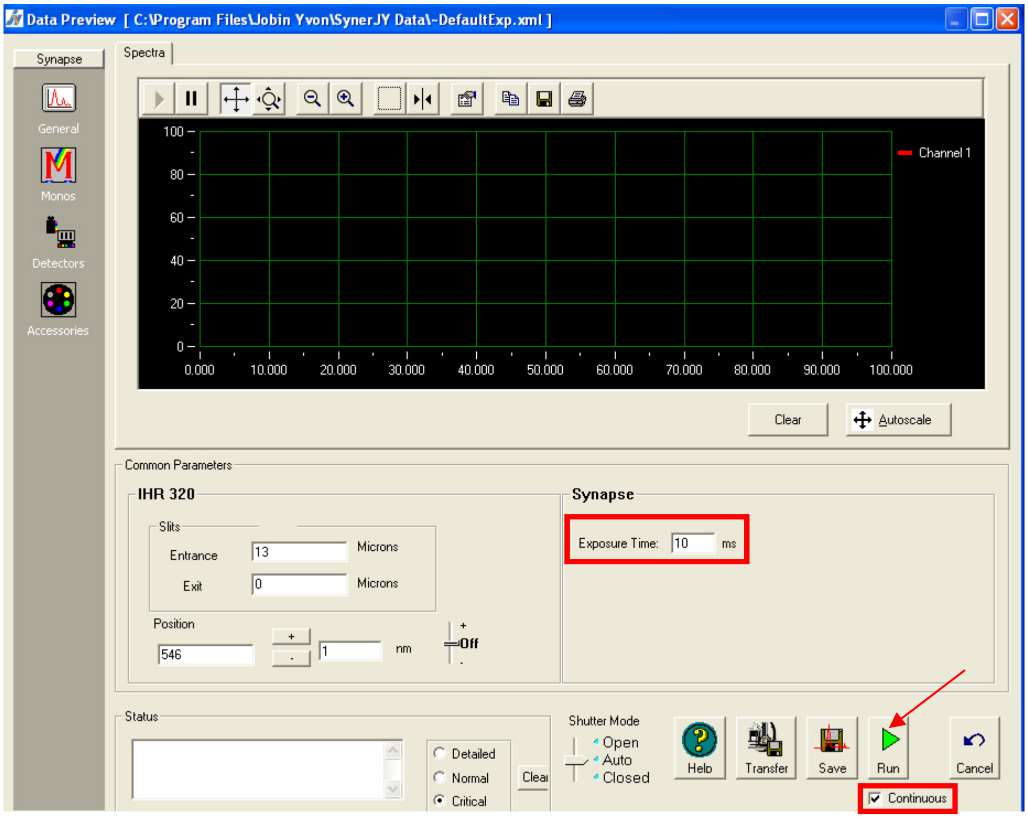
3. Enter an entrance slit width of 13 μm (.0130 mm) and manually set the height limiter to 1 mm.

4. Click the **Detectors icon** from the **General** tab. Click the **Active** check box to activate the detector and select **Spectra** as the **Acquisition Mode.** Select **CCD Position** as the experiment **Type** and enter a reference **Center Wavelength** (such as Hg line at 546 nm).



5. Click the **Advanced** button to view the **Advanced Multi-channel Parameters** screen. Set the data to display as signal intensity (Y-axis) vs. pixel position (X-axis). Click **OK** to close the window.

6. Click the **Preview** button to open **Data Preview** mode. Set the **Integration Time** to 0.1 second or less, and select the **Continuous** spectral acquisition check box.



7. **Run** the experiment for several seconds then click **Stop**.

8. **Zoom** in on the central peak.

9. View the spectra. A focused, aligned CCD will provide a distinct peak of large amplitude, generally symmetrical to the limits of the design of the spectrometer. The peak should be less than or equal to 5 pixels wide across the Full Width of Half the Maximum height (FWHM). Excessive asymmetry of the peak is a sign that the slit image is not aligned to the pixel columns; diminished shape and magnitude are symptomatic of defocusing.

10. **Stop** the acquisition.

11. While in **Data Preview**, select **Detectors** and set **five** equal areas in the **Free Form Area** list.

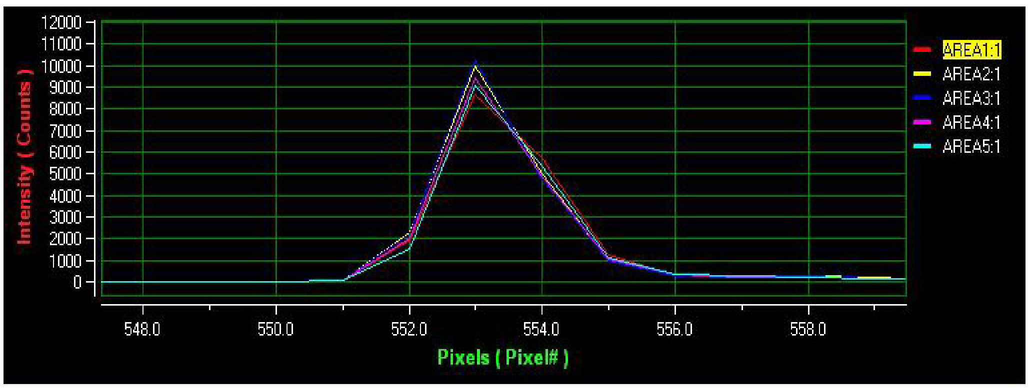
12. Click the **Reformat** button to display the areas then click Apply to apply the area change as a parameter.

13. Select **Continuous** and **Run** the experiment. When aligned the five spectra will overlap but may not show similar intensity. Each spectrum should be 3-5 pixels wide at FWHM. To adjust the focus of the CCD camera, rotate the focus wheel with your fingers to drive the CCD flange out from the body. To bring the camera focus in, it is necessary to hold the camera against the wheel while rotating the focus wheel.

14. To adjust the alignment (rotation) of the CCD camera, insert a 1.5 mm allen key into the hole in the side of the unit to engage the CCD rotation adjustment set

screw. Turning the screw into the body (clockwise) will push against the pin on the CCD flange rotating the camera. To rotate in the opposite direction, you need to turn the camera against the rotation adjustment screw while turning the screw counter-clockwise.

15. When the focus and alignment of the camera are properly set, tighten the flange lock to clamp the CCD flange in position.
16. To lock the focus wheel in its current position, turn off the light source, remove the top cover of the spectrograph and tighten the focus lock set screw. If it is necessary to remove the CCD for some reason, simply loosen the flange lock set screw and remove the CCD. This Quick-Align CCD adapter mechanism allows easy replacement of the CCD with minimal realignment.



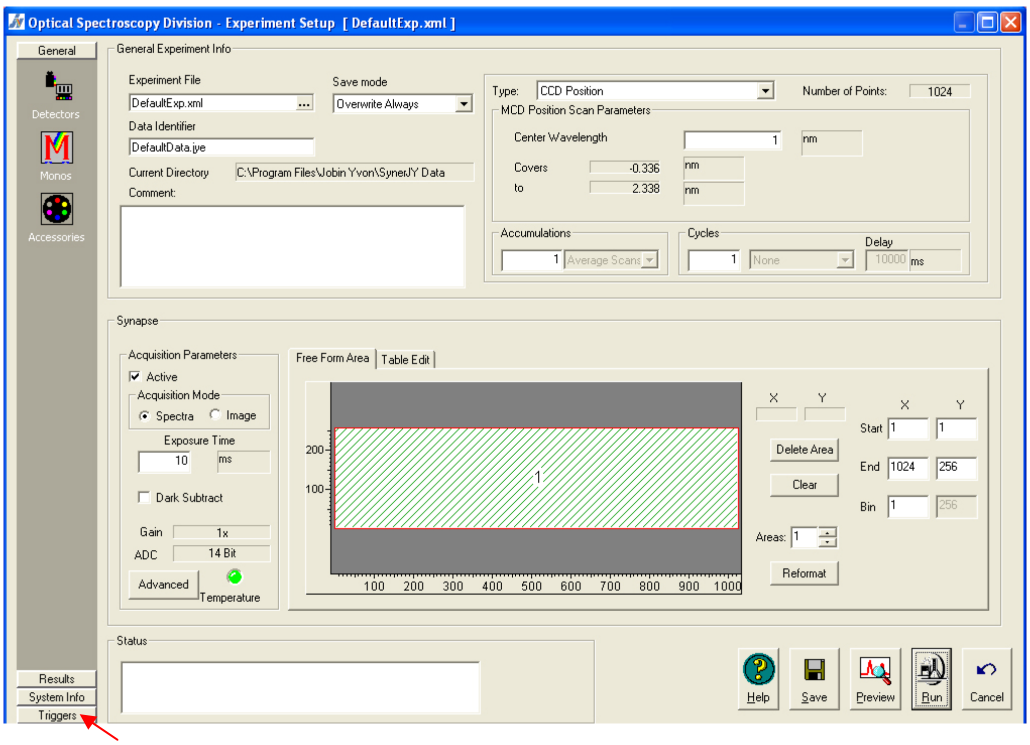
Triggering

Synapse detection systems offer both input and output TTL trigger functions. Triggering functions are software enabled. Two hardware triggers are available as SMB receptacles on the back of the controller: one for TTL input (male) and one for TTL output (female).

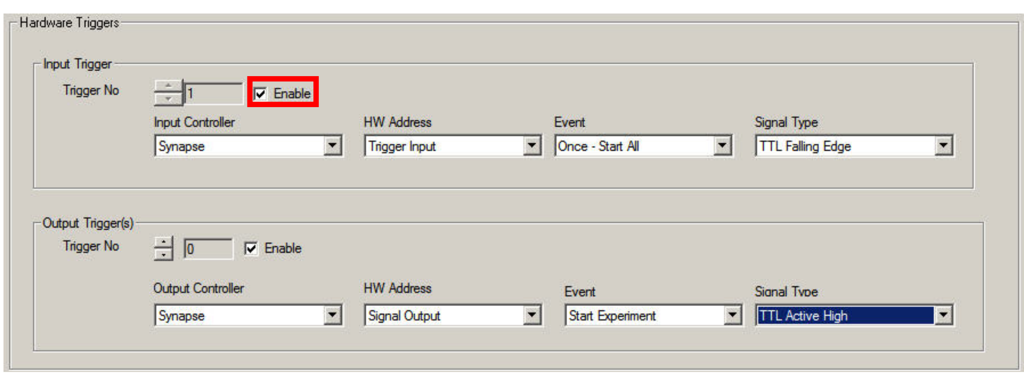
Triggering can be activated at the start of each experiment or at the start of each acquisition during the course of one experiment.

To enable triggering using SynerJY:

1. Start SynerJY and open the **Experiment Setup** screen.
2. Select the **Triggers** tab. The Triggers window will open.



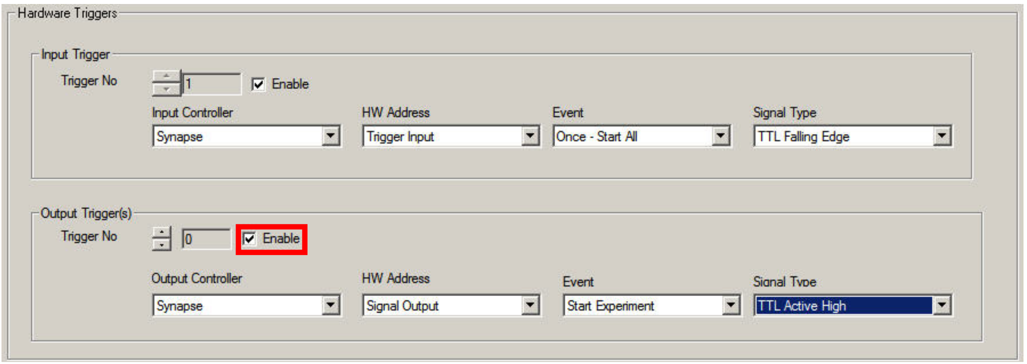
3. From the **Input Trigger** heading, click **Enable** to activate the **Input Trigger**.



4. Select the appropriate **Input Trigger** parameters. **Event** allows the user to specify whether the Trigger will be enabled once, at the start of the experiment or at the

start each acquisition (for multiple acquisition experiments). Select a **Signal Type** to indicate **TTL Rising Edge** or **TTL Falling Edge**.

5. From the **Output Trigger** heading click **Enable** to activate an **Output Trigger**.



6. Select the appropriate **Output Trigger** parameters. **TTL Output** can be used for **Experiment Running** functions or for **Each Shutter Open** or **Chip Readout** functions. Either **TTL Active Low** or **TTL Active High** can be selected as the **Signal Type**.
7. Click **Run** to start the experiment.

Using the Auxiliary Analog Input Port

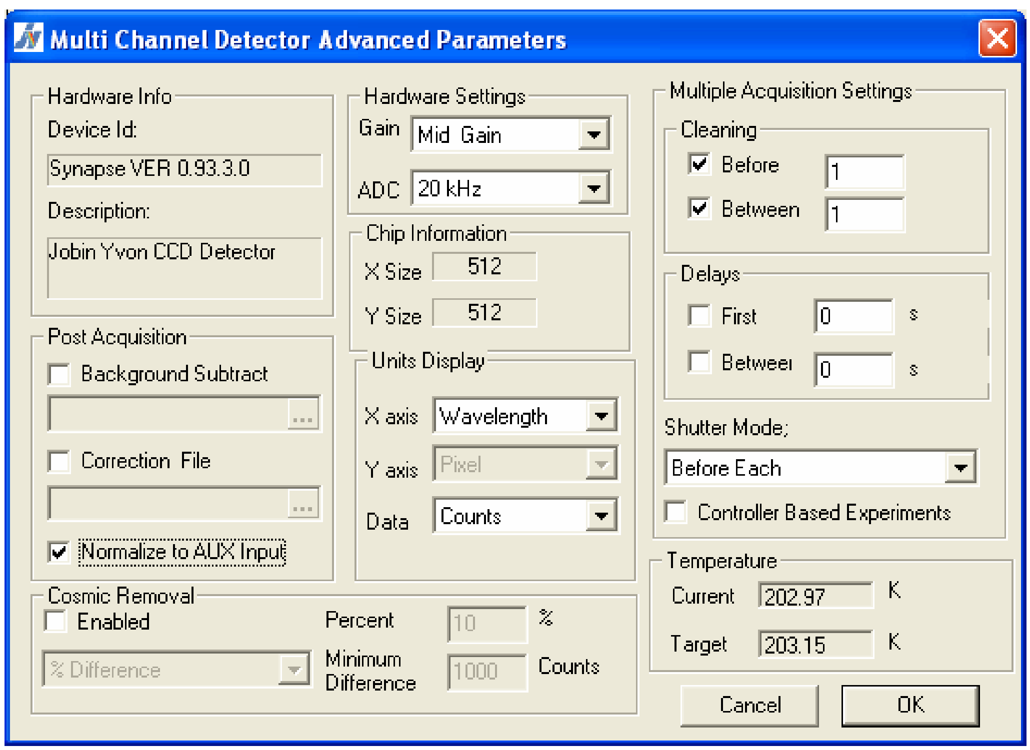
The Auxiliary Analog Input port (AUX IN) is designed to measure a voltage or current signal and can be used as an independent data acquisition channel or as a reference channel to correct CCD acquisitions for power fluctuations in an excitation source.

The AUX IN port accepts signals up to +/- 10 V in **Voltage** mode or up to +/- 10 µA in **Current** mode via an SMA connector and incorporates programmable gain capability (1/10/100/1000) to adjust for signal sensitivity as required.

Normalization (Reference)

To use the AUX port as a reference channel:

1. Start SynerJY and open the **Experiment Setup** screen.
2. Click the **Detectors icon** from the **General** tab. Click the **Active** check box to activate the detector. Select the **Acquisition Mode** and **Experiment Type** and enter any additional experiment parameters.
3. Click the **Advanced** button to view the **Multi Channel Detector Advanced Parameters** screen. Select the **Normalize to AUX Input** check box to enable Normalization (Uncheck the box to disable this feature). Click **OK** to close the window.

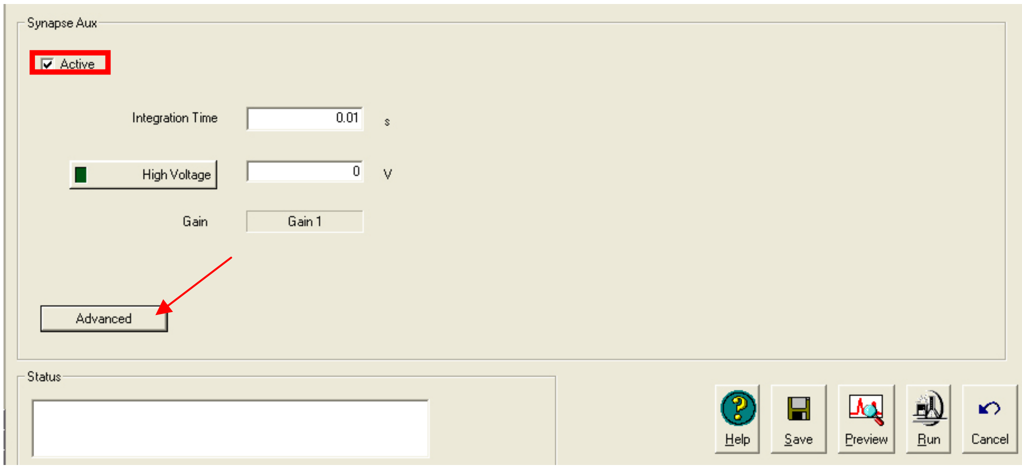


4. Click **Run** to start the experiment.
5. When the Normalize function is enabled, the Synapse CCD will collect data from the CCD and collect a reference value from the AUX IN port. The CCD data will then be divided by the value collected from the AUX IN port.

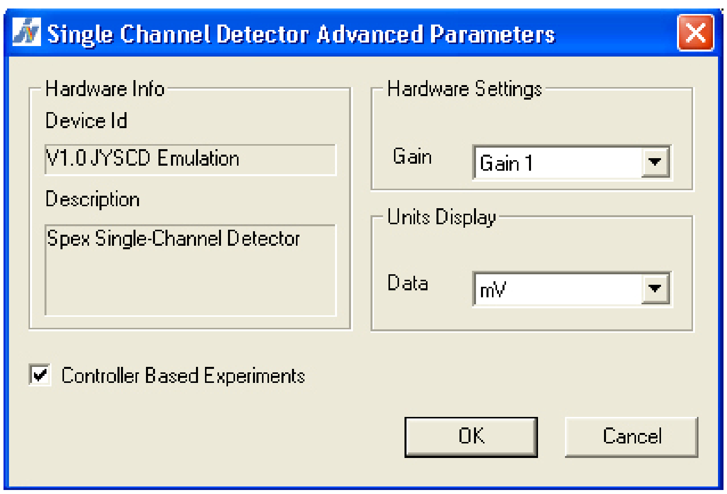
Independent Data Acquisition

To use the AUX IN as an independent data acquisition channel:

1. Make sure the detector is configured in SynerJY or the SDK as a **Single Channel Detector** (refer to the hardware configuration procedures of your software documentation).
2. Start SynerJY and open the **Experiment Setup** screen.
3. The Aux Port will appear as an option in the detectors list in **Experiment Setup** and **Data Preview**. Click the **Active** check box to activate the Aux Port.



4. Select the **Experiment Type** and enter any additional experiment parameters.
5. Click the **Advanced** button to view the **Single Channel Detector Advanced Parameters** screen. Select the proper **Units** and **Gain** settings. Click **OK** to close the window.



6. Click **Run** to start the experiment.

Configuring for Voltage and Current Modes

To switch Auxiliary Analog Input operation modes, you must create two separate **Single Channel Detector** configurations (one for **Voltage** and one for **Current**), both connected to the Synapse. When one of these detectors is initialized, the Synapse will automatically be configured as either a voltage or current device.

Appendix D: WEEE Recycling Passport

In compliance with the Waste Electrical and Electronic Equipment (WEEE) regulations specified in the Directive 2002/96/EC of the European Parliament and of the Council on waste electrical and electronic equipment dated January 27th 2003, HORIBA Jobin Yvon provides the following required information to facilitate reuse and treatment of the Synapse CCD Detection System. It should be noted that this electronic equipment falls under Category 9 (monitoring and control instruments) of Annex IA / IB of said document.

In addition, it should be emphasized that the overall Synapse CCD Detection System, consisting of a detector head and power supply unit, does not include any fluids and/or battery components (either external or internal to the product) as designated in Annex II of the aforementioned directive. Table VII below summarizes the complete list of components and materials incorporated in the Synapse CCD Detection System that require selective treatment as defined by this European directive.

Table VII. Summary of Synapse Detection System Material Requiring Selective Treatment

Item Description	Notes	Quantity of Items Included	
		Detector Head	Power Supply Unit
Capacitors / condensers containing PCB/PCT		0	0
Capacitors / condensers measuring > 25 mm in height or diameter		0	1
Mercury containing components		0	0
Batteries		0	0
Printed Circuit Boards & Assemblies	With surface area > 10 sq cm	5	3
Toner Cartridges, liquid & pasty, as well as, color toner		0	0
Plastics containing brominated flame retardants		0	0
Components & waste containing asbestos		0	0
Cathode Ray Tubes		0	0
CFCs, HCFC / HFCs, HCs		0	0
Gas Discharge Lamps		0	0
Liquid Crystal Displays (LCD) with a surface > 100 sq cm		0	0
External electrical cables / cords		0	2
Components containing refractory ceramic fibers		0	0
Components containing radioactive substances		0	0

From a product disassembly standpoint, Table VIII below denotes the required tools to disassemble the Synapse CCD Detection System to the point where incorporated components and/or materials can be removed for proper treatment.

Table VIII. Tools Required for Disassembly of the Synapse CCD Detection System

Tool Description	Tool Size
Phillips Head Screw Driver	#1 and #2
Hex Driver	1/16, 3/32 and 0.050
Wire Cutting Pliers	
Needle Nose Pliers	

The remainder of this appendix is dedicated to addressing the reuse and treatment associated with both the Synapse detector head and power supply unit. Detailed information is provided for each of these electronics boxes as follows:

- WEEE Product Marking
- General External View
- Dismantling Information
- Internal materials/components which: (a) can disturb the recycling process and (b) can normally benefit from reuse and treatment
- Complete Recycling Information including material weight breakdowns

WEEE Product Marking

Figures 19 and 20 illustrate the product markings for both the detector head and power supply unit making up the overall Synapse CCD Detection System. It should be noted that these markings comply with the requirements of Article 10 paragraph 3 and Article 11 paragraph 2 of the aforementioned WEEE Directive.

Both units, as depicted in the product marking figures, incorporate the “crossed-out wheel bin” symbol indicating that separate waste collection is required for this electrical / electronic equipment once its “end-of-life” has been reached. In addition, product markings for both units provide clear identification to the producer of said equipment (Horiba Jobin Yvon), as well as, incorporate a product serialization scheme that includes the both the week and year the product was manufactured. This serial numbering philosophy ensures complete delineation from the effective August 13th 2005 compliance date.

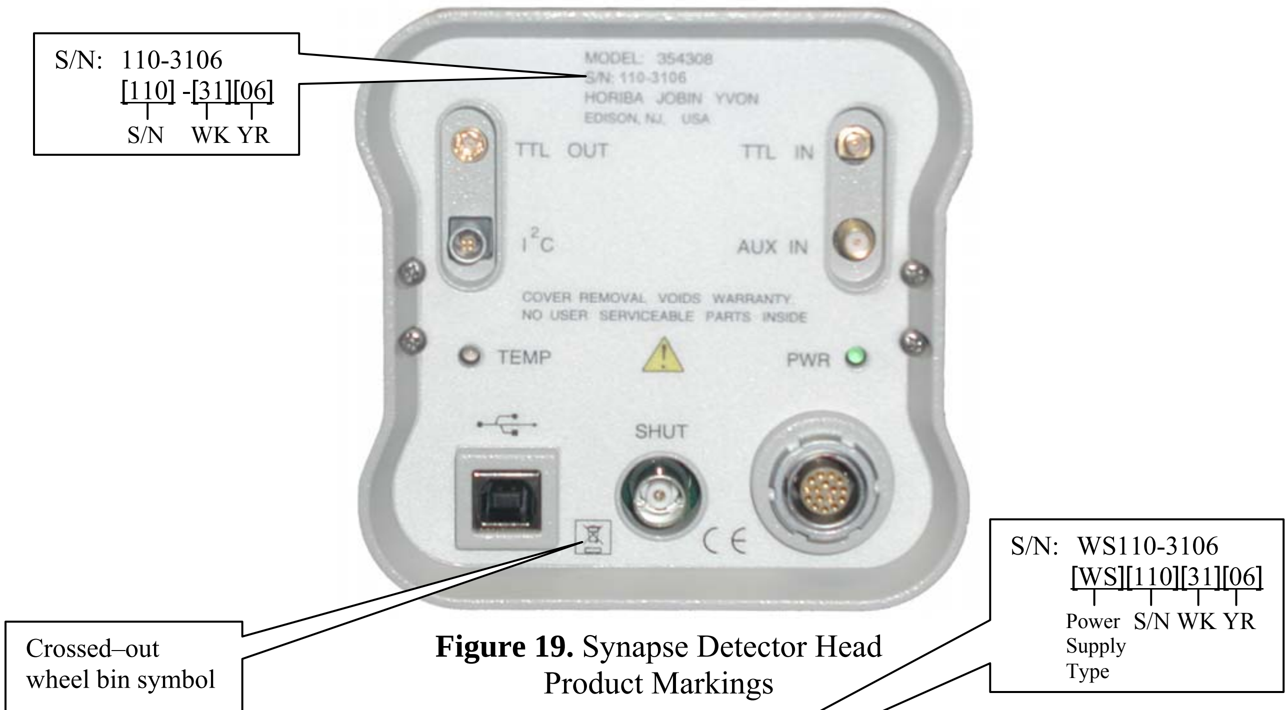


Figure 19. Synapse Detector Head Product Markings

Figure 20. Synapse Power Supply Unit Product Markings

General External View of Detector Head

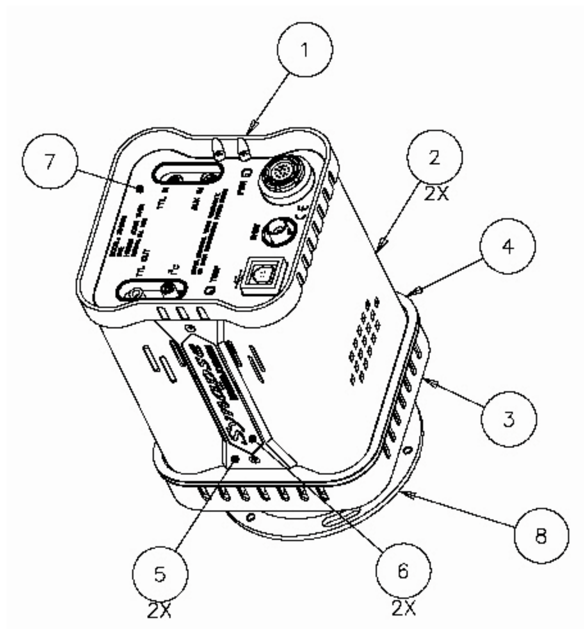


Figure 21. General View of Synapse Detector Head Indicating External Material for Recycling

Table IX. Breakdown of Synapse Recycling Components Viewed Externally

Number	Recycling/Material Code	Notes
4		Delrin spacer
6	Mixed plastic	Product labels, vinyl / polyurethane, 2 pcs
7		Product label, polycarbonate
1		Clear RoHS Iridite & RoHS Paint
2		Clear RoHS Iridite & RoHS Paint, 2 pcs
3	Aluminum	Clear RoHS Iridite & RoHS Paint
5		Clear RoHS Iridite & RoHS Paint, 2 pcs
8		Black Anodized

Dismantling of Detector Head

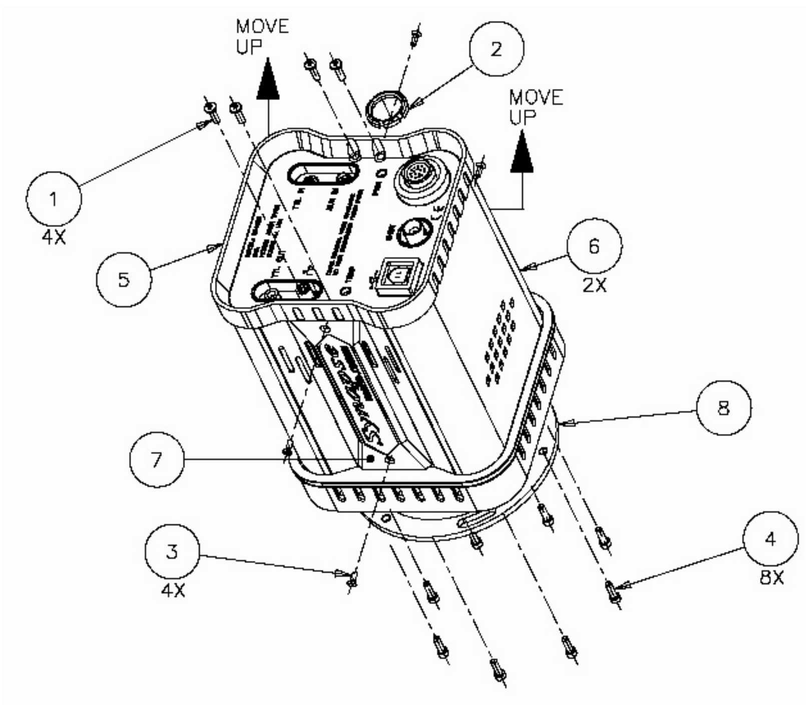


Figure 22. Illustration of the Dismantling Process for the Synapse Detector Head

Table X. Detector Head Disassembly Process

Number	Disassembly Process
1	Unscrew item 4 (8 places)
2	Remove item 8
3	Unscrew item 3 (4 places)
4	Remove item 7 (2 places)
5	Unscrew item 1 (4 places) and item 2
6	Remove item 5 by sliding it up
7	Remove item 6 by sliding it up (2 places)

Notes for Dismantling Detector Head

► Internal materials/components which: (a) can disturb several recycling processes and (b) can normally benefit from reuse and treatment.

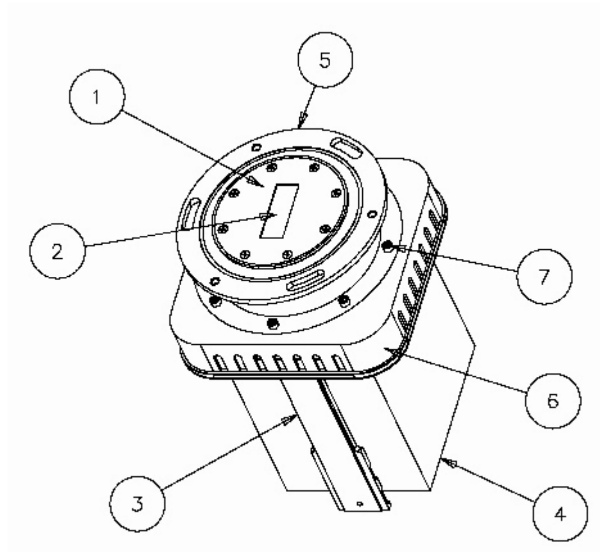


Figure 23. Synapse Detector Head Depicting Location of Internal Material for Recycling

Table XI. Breakdown of Internal Detector Head Recycling

Number	Recycling/Material Code	Important Information
Material/components, which can disturb certain recycling processes		
4	Electrolytic capacitors	Several small parts distributed on circuit boards. No parts with height and/or diameter > 25mm
4	Circuit boards	Internal to unit
2	Glass	Attached to nose piece
1	Thermo-electric cooler Charge Coupled Device	Located underneath stainless steel nosepiece and attached to baseplate
7	Mixed metal	Small single parts, screws, washers
4	Mixed plastic	Delrin part
Material/components, through which benefits can be normally be achieved		
1	Stainless steel	Unit nose piece located inside black anodized flange
5	Aluminum	Mounting flange, unit exterior, black anodized
3	Aluminum	Unit interior, clear RoHS Iridite, 2 pcs
6	Copper	Internal Cu baseplate located inside RoHS compliant painted aluminum front cover
4	Fan	Internal to unit
4	Cables	Distributed in the device

Complete Recycling Data of Detector Head

Table XII. Complete Recycling Data of Detector Head

Recycling/Material Code	Approx. Weight (kg)	Notes
Material/components, which must be removed and treated separately		
None	0.000	Not Applicable
Subtotal	0.000	
Material/components, which can disturb certain recycling processes		
Electrolytic capacitors		Several small parts distributed on circuit boards. No parts with height and/or diameter > 25mm
Circuit boards	0.288	Internal to unit
Glass	0.014	Attached to nose piece
Thermo-electric cooler	0.011	Attached to baseplate
Charge Coupled Device	0.008	Attached to thermo-electric cooler
Mixed metal	0.029	Small single parts, screws, washers
Mixed plastic	0.068	Delrin parts (2), lens cover, product labels (3)
Subtotal	**0.418**	
Material/components, through which benefits can be normally be achieved		
Stainless steel	0.130	Unit nose piece
Aluminum	0.352	Unit exterior, clear RoHS Iridite & RoHS Paint, 6 pcs
Aluminum	0.130	Unit exterior, black anodized
Aluminum	0.062	Unit interior, clear RoHS Iridite, 4 pcs
Copper	0.964	Unit internal baseplate / cold bar
Fan	0.051	Internal to unit
Cables	0.001	Distributed in the device
Subtotal	**1.690**	
Composite materials		
Steel/plastic	0.000	Not Applicable
Subtotal	0.000	
TOTAL WEIGHT	**2.108**	
Special Notes:		

General External View of Power Supply Unit

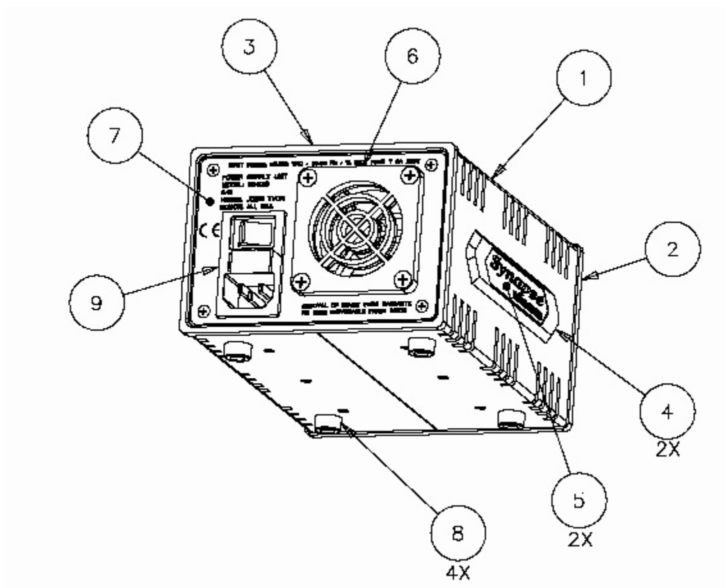


Figure 24. General View of Synapse Power Supply Unit Indicating External Material for Recycling

Table XIII. Breakdown of Power Supply Unit Recycling Components Viewed Externally

Number	Recycling/Material Code	Notes
8	Rubber	Rubber feet
5	Mixed plastic	Product labels, vinyl / polyurethane, 2 pcs
6		Fan filter dust guard
7		Product label, polycarbonate
9		Power entry module, RoHS compliant
1	Aluminum	Clear RoHS Iridite & RoHS Paint
2		Clear RoHS Iridite & RoHS Paint
3		Clear RoHS Iridite & RoHS Paint
4		Clear RoHS Iridite & RoHS Paint, 2 pcs

Dismantling of Power Supply Unit

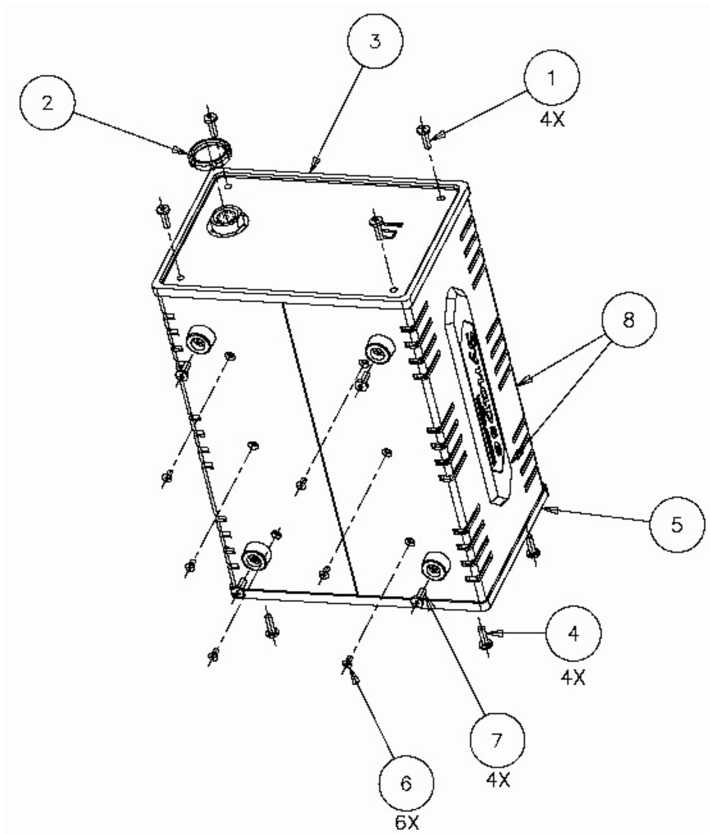


Figure 25. Illustration of the Dismantling Process for the Synapse Power Supply Unit

Table XIV. Power Supply Unit Disassembly Process

Number	Disassembly Process
1	Unscrew item 4 (4 places)
2	Remove item 5
3	Unscrew item 1 (4 places) and item 2
4	Remove item 3
5	Unscrew item 7 (4 places)
6	Unscrew item 6 (6 places)

Notes for Dismantling Power Supply Unit

► Internal materials/components which: (a) can disturb several recycling processes and (b) can normally benefit from reuse and treatment.

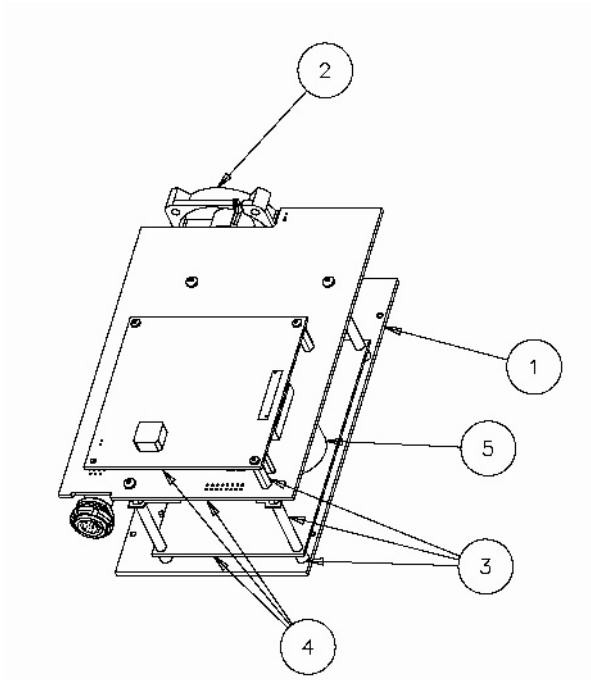


Figure 26. Synapse Power Supply Unit Depicting Location of Internal Material for Recycling

Table XV. Breakdown of Internal Power Supply Unit Recycling

Number	Recycling/Material Code	Important Information
Material/components, which can disturb certain recycling processes		
5	Electrolytic capacitors	Only One component with diameter > 25mm located on power supply circuit board
4	Circuit boards	Internal to unit
Material/components, through which benefits can be normally be achieved		
1	Aluminum	Unit interior, clear RoHS Iridite, 2 pcs
3	Aluminum	Small single parts, stand-offs
2	Fan	Internal to unit
	Cables	Distributed in the device

Complete Recycling Data of Power Supply Unit

Table XVI. Complete Recycling Data of Power Supply Unit

Recycling/Material Code	Approx. Weight (kg)	Notes
Material/components, which must be removed and treated separately		
None	0.000	Not Applicable
Subtotal	0.000	
Material/components, which can disturb certain recycling processes		
Electrolytic capacitors		Only one component with diameter > 25mm located on power supply circuit board
All other Circuit boards	0.448	Internal to unit
Power supply circuit board	0.116	RoHS compliant (weight excludes magnetic parts)
Power entry module	0.036	RoHS compliant
Mixed metal	0.015	Small single parts, screws, washers
Mixed plastic	0.020	Fan filter dust guard, product labels
Rubber	0.002	Rubber feet located externally on bottom of unit
Subtotal	**0.637**	
Material/components, through which benefits can be normally be achieved		
Aluminum	0.601	Unit exterior, clear RoHS Iridite & RoHS Paint, 5 pcs
Aluminum	0.130	Unit interior, 2 plates, small single parts, stand-offs
Aluminum	0.058	Heatsink, Part of power supply board, clear RoHS Iridite
Transformer / Inductors	0.155	Part of power supply board
Fan	0.017	Internal to unit
Cables	0.008	Distributed in the device
Subtotal	**0.969**	
Composite materials		
Steel/plastic	0.000	Not Applicable
Subtotal	0.000	
TOTAL WEIGHT	**1.606**	
Special Notes:		

Appendix E: Accessories

Table XVII. Available Accessories for Synapse

Accessory	Part Number
TTL Shutter Out Cable, SMB Jack to BNC Male, 4 Ft TTL Ext Trig In Cable, SMB Plug to BNC Male, 4 Ft	CCA-SYNAPSE-TRIG
Shutter driver for controlling additional shutters; uses CCA-SYNAPSE-TRIG to synchronize with primary shutter.	CCD-SHUTTER-DRIVER

Service Policy

If you need assistance in resolving a problem with your instrument, contact our Customer Service Department directly, or if outside the United States, through our representative or affiliate covering your location.

Often it is possible to correct, reduce, or localize the problem through discussion with our Customer Service Engineers.

All instruments are covered by warranty. The warranty statement is printed inside of this manual. Service for out-of-warranty instruments is also available, for a fee. Contact HORIBA Jobin Yvon or your local representative for details and cost estimates.

If your problem relates to software, please verify your computer's operation by running any diagnostic routines that were provided with it. Please refer to the software documentation for troubleshooting procedures. If you must call for Technical Support, please be ready to provide the software serial number, as well as the software version and firmware version of any controller or interface options in your system. The software version can be determined by selecting the software name at the right end of the menu bar and clicking on “About.” Also knowing the memory type and allocation, and other computer hardware configuration data from the PC's CMOS Setup utility may be useful.

In the United States, customers may contact the Customer Service department directly. From other locations worldwide, contact the representative or affiliate for your location.

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If an instrument or component must be returned, the method described on the following page should be followed to expedite servicing and reduce your downtime.

Return Authorization

All instruments and components returned to the factory must be accompanied by a Return Authorization Number issued by our Customer Service Department.

To issue a Return Authorization number, we require:

- The model and serial number of the instrument
- A list of items and/or components to be returned
- A description of the problem, including operating settings
- The instrument user's name, mailing address, telephone, and fax numbers
- The shipping address for shipment of the instrument to you after service
- Your Purchase Order number and billing information for non-warranty services
- Our original Sales Order number, if known
- Your Customer Account number, if known
- Any special instructions

Warranty

For any item sold by Seller to Buyer or any repair or service, Seller agrees to repair or replace, without charge to Buyer for labor or materials or workmanship of which Seller is notified in writing before the end of the applicable period set forth below, beginning from the date of shipment or completion of service or repair, whichever is applicable:

a. New equipment, product and laboratory apparatus: 1 year with the following exceptions:

   i) Computers and their peripherals

   ii) Glassware and glass products.

b. Repairs, replacements, or parts – the greater of 30 days and the remaining original warranty period for the item that was repaired or replaced.

c. Installation services – 90 days.

The above warranties do not cover components manufactured by others and which are separately warranted by the manufacturer. Seller shall cooperate with Buyer in obtaining the benefits of warranties by manufacturers of such items but assumes no obligations with respect thereto.

All defective items replaced pursuant to the above warranty become the property of Seller.

This warranty shall not apply to any components subjected to misuse due to common negligence, adverse environmental conditions, or accident, nor to any components which are not operated in accordance with the printed instructions in the operations manual. Labor, materials and expenses shall be billed to the Buyer at the rates then in effect for any repairs or replacements not covered by this warranty.

This warranty shall not apply to any HORIBA Jobin Yvon manufactured components that have been repaired, altered or installed by anyone not authorized by HORIBA Jobin Yvon in writing.

THE ABOVE WARRANTIES AND ANY OTHER WARRANTIES SET FORTH IN WRITING HERIN ARE IN LIEU OF ALL OTHER WARRANTIES OR GUARANTEES EXPRESSED OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY, FITNESS FOR PURPOSE OR OTHER WARRANTIES.

The above shall constitute complete fulfillment of all liabilities of Seller, and Seller shall not be liable under any circumstances for special or consequential damages, including without limitation loss of profits or time or personal injury caused.

The limitation on consequential damages set forth above is intended to apply to all aspects of this contract including without limitation Seller’s obligations under these standard terms.

Glossary of Terms

The discussion of light detection with Charge Coupled Devices (CCDs) requires some familiarity with the terminology used. This section includes definitions specific to this context for some familiar terms, as well as several unique terms, abbreviations and acronyms.

Accumulations

Accumulations are the number of repetitions for which the detector collects data and averages the results to obtain a better signal-to-noise ratio.

ADC

An Analog to Digital Converter (ADC) converts a sample of an analog voltage or current signal to a digital value. The value may then be communicated, stored, and manipulated mathematically. The value of each conversion is generally referred to as a data point.

Advanced Inverted Mode Operation (AIMO)

Advanced Inverted Mode Operation (AIMO) is a mode of operation specific to E2V CCD chips that significantly reduces dark current generation, thereby allowing thermo-electric cooling of the sensor to be more than adequate for most applications. This mode of operation is also referred to as MPP, which is also discussed in this glossary section.

Areas

Areas are defined as the active sections of the CCD detector. Signals that encounter sections of the CCD that are not part of an active area are not recorded. Once an area is specified, the area definitions refer to the number of areas and the size of the areas.

Back-thinning

Back-thinning is a process where the CCD substrate is etched down to be very thin (≈ 10 µm), so that incident light can be focused on the backside of the chip where its depletion layer is not obstructed by the chip's physical gate structure. This thinning technique increases the CCD's photon sensitivity as illustrated by the higher quantum efficiency (QE) exhibited by these back-illuminated devices. It should be noted that back-thinned chips are sensitive to etaloning effects from the 700 nm to 1100 nm wavelength range (see Etaloning).

Binning

Binning is the process of combining charge from adjacent pixels and can be performed in both the vertical (Y) and horizontal (X) directions. For example, a binning factor of 2 x 2 corresponds to the combination of two pixels in both the X and

Y directions producing one "super" pixel equivalent to the total charge of the four original pixels. It should be noted that binning does reduce resolution capability; however, it increases sensitivity and improves (i.e. lowers) the overall CCD readout time. End-users are cautioned that there is a limit to the effectiveness of hardware binning as a result of the horizontal serial shift register and output node not having infinite capacity to store charge. This physical limitation is best exemplified for applications that have a very small signal superimposed on a large background. In practice, the pixels associated with the horizontal register have twice the full well capacity of their light sensitive counterparts, while the output node usually can hold four times that of the photosensitive area. Thus, experiments where the summed charge exceeds either the full well capability of the horizontal shift register and/or the output node will be lost from a data processing point of view.

Charge Coupled Device

A Charge Coupled Device (CCD) is a light sensitive silicon chip that is used as a two-dimensional photo-detector in digital cameras for both imaging and spectroscopic applications. With respect to spectroscopic applications, the CCD simultaneously measures intensity, X-position (wavelength) and Y-position (slit height) differences projected along the spectrograph image plane.

CCD sensors are offered by a number of manufacturers and come in a variety of sizes, chip architectures and performance grades to best meet the application at hand.

Charge Transfer Efficiency (CTE)

The percentage of charge moved from one pixel to the next is the charge transfer efficiency. The CCD has a high CTE if the pixels are read out slowly. As the speed at which the charge is transferred is increased, increasing amounts of the charge is left behind. The residual charge combines with the charge of the next pixel as it is moved into the cell. Therefore, using too high a transfer rate deforms the image shape; it smears the charge over the pixels that follow in the readout cycle. Temperature also affects CTE. Under normal operation the CTE is approximately 99.9995%. Below –140 °C the movement of the charges becomes sluggish, and, again, the image becomes smeared.

Correlated Double Sampling (CDS)

This sampling method utilizes a differential measurement technique to achieve a higher precision measurement for each pixel processed during the CCD readout cycle. This difference measurement (B-A) is accomplished by making two voltage measurements for each pixel processed as follows:

- Measurement A: Residual output amplifier charge during CCD reset time
- Measurement B: Real charge plus the residual associated with the current pixel being processed

Electronic circuitry that employs this CDS measurement technique is especially important to properly characterize pixel response at low signals levels, since a minute

residual charge always remains present on the CCD output node even after the CCD's reset gate has been activated once a pixel has been read out. Thus, this process ensures that only the true charge associated with the current pixel being processed is measured.

Cosmic Ray Events

Cosmic Rays are high-energy particles from space, mostly attributed from the sun. They will generally be detected by a scientific grade detection system, since the cooled CCD offers extremely low dark signal level. In the active area of a typical array, about 5 events per minute per sensor cm^2 may occur. Compared to very weak signals from the experiment at hand, detected comic ray events can be quite distracting. To minimize the effects of these rays, the end-user can utilize the smallest section of the chip required by the experiment, as well as, use the smallest integration time possible. In addition, mathematical treatment of the data can also be used to remove these spurious spikes in the spectra. Please refer to the SynerJY software manual for more information about cosmic removal.

Dark Signal

Dark signal is generated by thermal agitation. This signal is directly related to exposure time and increases with temperature. The dark signal doubles with approximately every 7 ^{o}C increase in chip temperature. The more the dark signal, the less dynamic range will be available for experimental signal. This signal accumulates for the entire time between readouts or flushes, regardless of whether the shutter is open or closed. Dark signal is also generated during the charge transfer cycles of the CCD. The problem is not necessarily the dark signal, but the noise in measuring the signal that adversely affects the data.

Dark Signal Nonuniformity (DSNU)

Dark signal nonuniformity (DSNU) is the peak-to-peak difference between the dark signal generation of the pixels on a CCD detector in a dark exposure.

Dynamic Range

Dynamic Range is the ratio of the maximum and minimum signal measurable. For a 16-bit detection system, the ideal / optimum dynamic range would be represented by 65,535:1. With respect to a CCD, this performance figure of merit corresponds to the ratio of a pixel's full well saturation charge to the output amplifier's read noise. It should be noted that the pixel's full well saturation charge correlates directly to the CCD's well capacity and varies with the device's pixel size and overall structure.

A more useful calculation of dynamic range, so far as a CCD sensor is concerned, centers around the "effective system" dynamic range. This system level parameter corresponds to the ratio of a CCD pixel's "linear" full well saturation charge to the total system noise level.

$$\text{Effective System Dynamic Range} = \frac{\text{Pixel Linear Full Well Saturation Charge}}{\text{Total System Noise}}$$

Here, the total system noise takes into account the CCD array's read noise, as well as, the noise contribution from the detector system's electronics as follows:

$$e_{\text{Total System Noise}} = \sqrt{e^2_{\text{CCD Read Noise}} + e^2_{\text{Electronics Noise}}}$$

It is important to note that the above calculation for total system noise assumes a 1 ms integration time and ignores the noise contributions from the array's dark current shot noise and the signal itself (i.e. shot noise).

Electrons/Count

Electrons per count is a system level "transfer function" parameter or gain related value that equates the number of electrons required to generate a single ADC count.

Etaloning

When a very thin piece material is used as an optical component, multiple interference patterns may be observed. This effect is called **Etaloning**. When the thickness of the material is on the order of the wavelength of light passed through, etaloning may prevent the detector from distinguishing an actual signal from the interference pattern. Etaloning is problematic with backthinned CCD chips in the wavelength range 700 nm to 1100 nm.

Felgett's Advantage

Multi-channel detection provides an improvement in signal to noise ratio, as compared to single channel (scanned) spectral detection. Because the multi-channel detection acquires a number of spectral elements simultaneously, the S/N is improved by a factor proportional to the square root of the number of channels acquired given the experiment times are equal.

Flush

To reduce noise and maximize dynamic range at the CCD, the dark charge that has accumulated on the chip can be rapidly removed by flushing. The effect of flushing the array is similar to a readout cycle in that the charges are cleared from the pixels. A flush is much faster than a frame readout since it dumps the charges without conversion. Flushing is only necessary when there is an appreciable time between readouts.

Full Well Capacity

Full well capacity is the measure of how much charge can be stored in an individual pixel. This specification varies for each chip type. It depends on the doping of the silicon, architecture and pixel size. The quantum well capacity is usually around 300,000 electrons. The greater the well, the greater the **Dynamic Range**. A chip with a larger full well capacity can record a higher signal level before saturating. See also **Variable Gain**.

Gain

Gain is the conversion between electrons generated in the CCD to counts reported in the software. Gain is typically set to be just below the read noise for most low light measurements, or set to take advantage of the full dynamic range for larger signals. Typically, because CCDs are extremely low noise devices, meaningful gains as low as 1 –2 electrons per count can be achieved. See also **Variable Gain.**

Integration Time

The amount of time for which the CCD is exposed to light and acquires data.

Linearity

When photo response is linear, if the light intensity doubles, the detected signal will double in magnitude as well. Nonlinear response at medium to high intensities is usually due to amplifier problems, and at very low light levels poor charge transfer efficiency. A CCD's response is linear, once the bias is subtracted.

Multi Phase Pinning (MPP)

Multi Phase Pinning (MPP) is a mode of operation specific to certain CCD brand names, such as E2V and Hamamatsu, that offer extremely low dark current operation. See also AIMO.

Noise

Noise is common to all detectors and associated camera systems. The total amount of real signal that exists in an experiment is less important than the ratio of the signal's magnitude to the total system noise that exists. This signal to noise ratio (S/N) is more commonly referred to as the system's effective dynamic range (see also Dynamic Range). Thus, for detector systems with a high S/N figure, a signal peak can be discerned even though signal counts per second may be low. A detector system's total system noise is comprised of the noise sources listed below and is defined as follows:

$$e_{\text{Total System Noise}} = \sqrt{e^2_{\text{CCD Read Noise}} + e^2_{\text{Electronics Noise}} + e^2_{\text{CCD Shot Noise}}}$$

It should be noted that for applications that have high intensity signals, the shot noise from the signal itself dominates the system's total noise. Conversely, for experiments that involve the detection of very weak signals, the system's total noise is dominated by the CCD related read noise and dark noise along with the ever present electronics noise source.

- **Electronics Noise (e electronics noise)**

  Noise that is introduced in the process of electronically amplifying and conditioning the detector signal, as well as, the ADC conversion noise associated with digitizing the pixel information.

- **CCD Read Noise (e ccd read noise)**

  Noise that is generated by the CCD's on-chip output amplifier. This noise parameter is frequency dependent and will increase with increased pixel processing times.

- **CCD Dark Noise (e ccd dark noise)**

  Noise that is generated due to the random statistical variations of the dark current and is equal to the square root of the dark current. It should be noted that dark current can be subtracted from an image or spectra and will not contribute to the total system noise; however, the dark noise remains. In addition, cooling the array can significantly reduce the accumulation of dark current and its associated dark noise.

- **CCD Shot Noise (e ccd shot noise):**

  Noise that is generated due to the random statistical variations associated with light. Shot noise is equal to the square root of the number of electrons generated.

Photoelectric Effect

Some materials respond to light by releasing electrons. When light of sufficient energy hits a photosensitive material, an electron is freed from being bound to a specific atom. Such materials include the P-N junctions of the silicon photodiodes used in CCD arrays. The energy of the light must be greater than or equal to the binding energy of the electron to free an electron. The shorter the wavelength, the higher the energy the light has.

Photoelectron

A photoelectron is an electron that is released through the interaction of a photon with the active element of a detector. The photoelectron could be released either from a junction to the conduction band of a solid-state detector, or from the photocathode to the vacuum in a PMT. A photoelectron is indistinguishable from other electrons in any electrical circuit.

Photo Response Nonuniformity (PRNU)

PRNU is the peak-to-peak difference in response between the most and least sensitive elements of an array detector, under a uniform exposure giving an output level of $V_{Sat}/2$. These differences are primarily caused by variations in doping and silicon thickness.

Quantum Efficiency (QE)

The efficiency of a detector's photoelectric effect is quantified by the ratio of the number of photoelectrons produced to the number of photons impinging on the CCD's photoactive surface. For example, a QE of 20% would indicate that one photon in five would produce a distinguishable photoelectron.

The quantum efficiency of a detector is determined by several factors that include: (1) the material's intrinsic electron binding energy or band gap, (2) the surface reflectivity and thickness and (3) the energy of the impinging photon. It should also be noted that QE varies with the wavelength of the incident light, as illustrated by the fact that standard "front illuminated" CCDs generally have a peak QE of 45-50% at around 750 nm. Back-thinned CCDs typically have improved QE curves, compared with their "front illuminated" counter-parts, that produce peak QE's in the 80-85% range. Additionally, the QE response of "front illuminated" devices can be improved by coating the chip with a fluorescent dye that converts UV light to longer wavelengths where the quantum efficiency of the CCD is higher.

Readout Time

The readout time of a CCD is the interval required to move the charges from their photo-sensitive locations to the readout register, sample and amplify the charges and then digitize them into discrete digital data points. Included in this readout time is the correlated double sampling (CDS) technique, which generally requires more processing time per pixel compared with other less accurate measuring methods. It should be noted that faster readout times increase the total system noise thereby reducing the effective system dynamic range. See also Correlated Double Sampling and Dynamic Range.

Responsivity

Responsivity is the absolute QE sensitivity given in units of amps/watt. CCDs are typically characterized by performance factors such as QE, counts and gain (specified in electrons/count) instead of responsivity.

Saturation Level

The maximum signal level that can be accommodated by a device is its saturation level. At this point, further increase in input signal does not result in a corresponding increase in output. This term is often used to describe the upper limit of a detector element, an amplifier, or an ADC.

Spectral Response

Most detectors will respond with higher sensitivity to some wavelengths than to others. The spectral response of a detector is often expressed graphically in a plot of responsivity or QE versus wavelength.

Time Interval

The elapsed time between the start of one accumulation to the start of the next accumulation. The Time Interval, Integration Time and Readout Time of the CCD detector have the following relationship:

$$t_{\text{interval}} \geq t_{\text{integration}} + t_{\text{read}}$$

UV Overcoating (Enhancement)

The depth of penetration into silicon is very shallow for UV light. With this shallow penetration, the probability of a UV photon penetrating to the depletion zone is less than for longer wavelength photons. Thus the QE is lower in the UV than in the visible and NIR region. By coating the chip with a fluorescent dye that converts UV light to longer wavelengths, the probability of photon detection is increased. Lumigen is a phosphor coating used for UV enhancement.

Variable Gain

Variable Gain is the ability to match the range of the ADC to the usually larger range of the CCD without losing valuable information.

Signal can be extracted from the noise baseline by statistical treatment. Oversampling of this noise will make this extraction more accurate, so the gain can be electronically adjusted to quantize this small signal at high resolution, typically 1 or 2 electrons per count. Since stronger signals saturate the ADC quicker, low electrons per count is considered high gain (a small signal produces a large response).

Conversely, large optical signals can tax the full dynamic range available on the chip, which may be in excess of the ADC dynamic range. In this case, a lower gain of typically 7 – 18 electrons per count will report a smaller count value versus a high gain setting, and allow the range of the ADC to cover the maximum charge of the CCD. Statistical information in the baseline is generally not the limiting factor of an acquisition with full range signals present, and thus can be traded off without penalty.

X Binning

X Binning is the combining of columns of pixels to form a single data point. By combining columns, a greater signal level can be detected; however, this results in a decrease in resolution. See Binning.

Y Binning

Y Binning is the combining of rows of pixels to form a single data point. By combining rows, a greater signal level can be detected; however, this results in a decrease in resolution. See Binning.

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